HE EAST AFRICAN CIRCULATE

AGRICULTURAL JOURNAL

of

ENYA
ANGANYIKA
GANDA AND
ANZIBAR

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ol. XV—No. 2

OCTOBER
1949

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Price
Sh. 1/25

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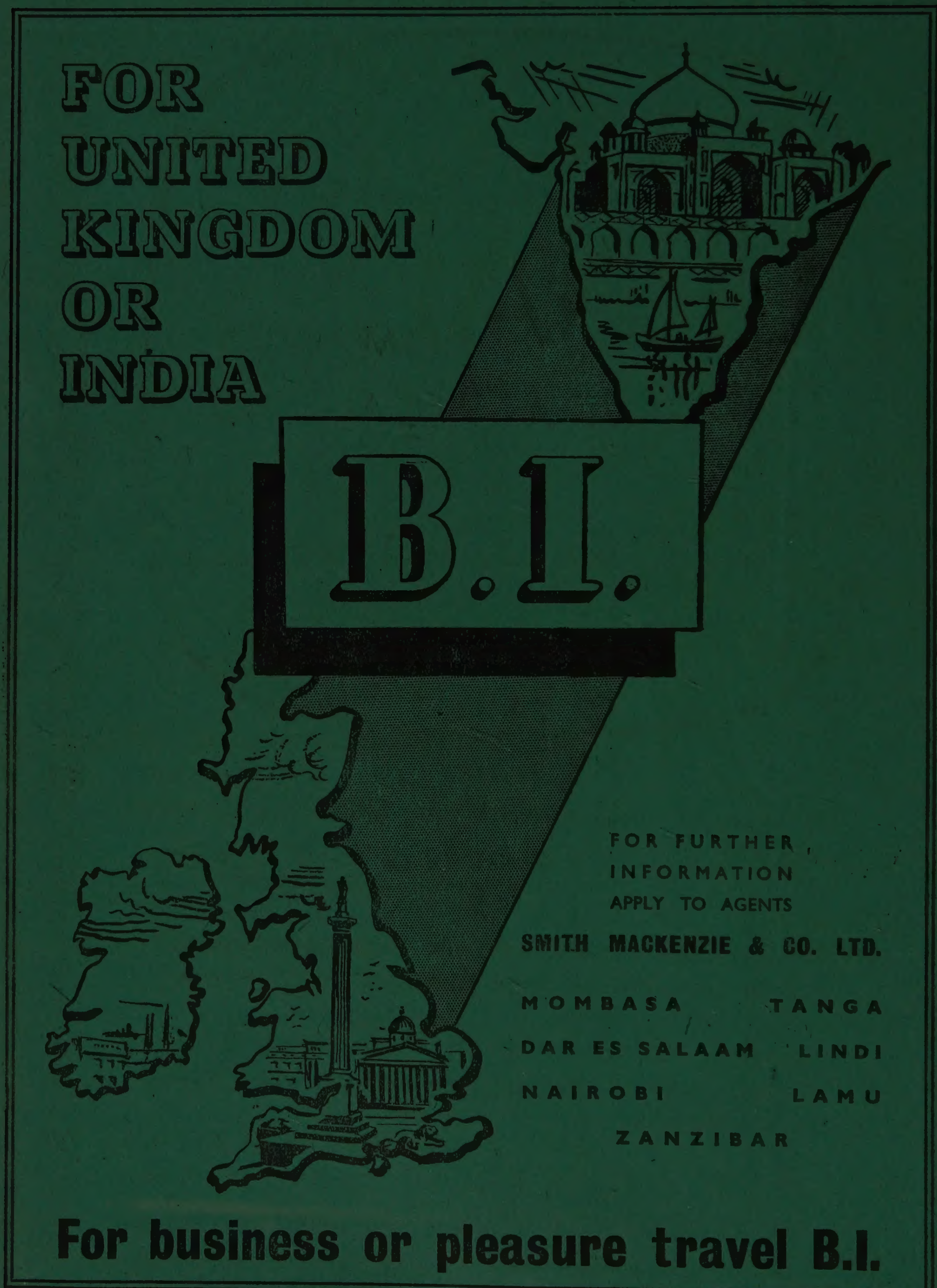
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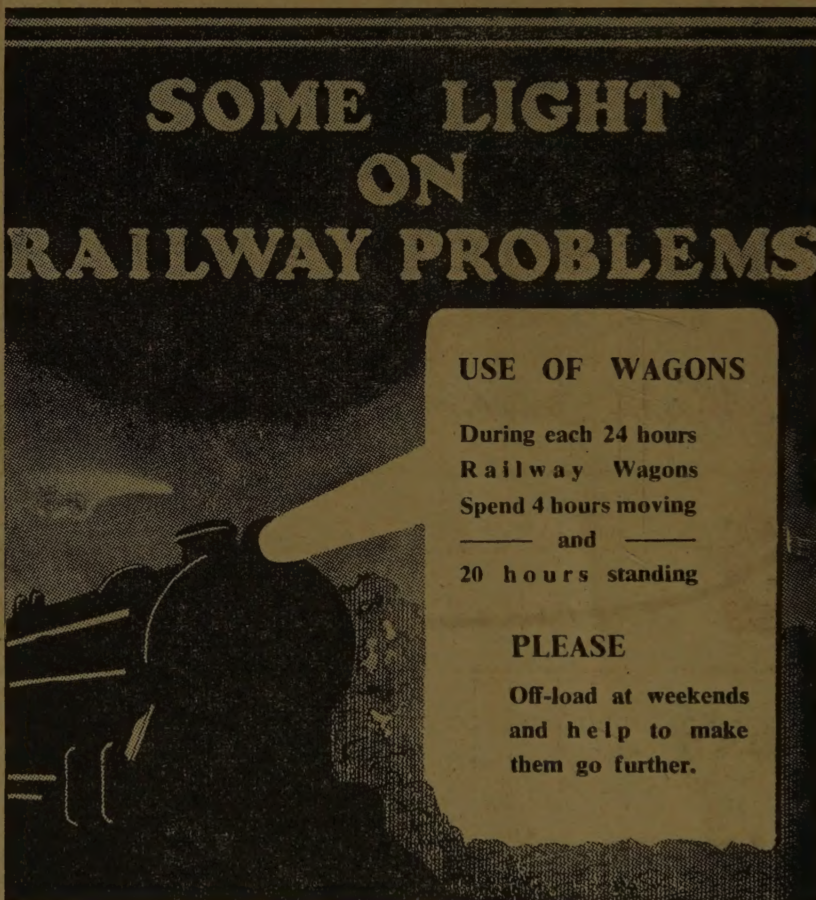
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EAST AFRICAN AGRICULTURAL JOURNAL

Vol. XV—No. 2 **OCTOBER, 1949**

Issued under the Authority of the East Africa High Commission and published every three months—July, October, January, April. Volume consists of four issues (commencing July issue).

EDITOR: D. W. DUTHIE,

E.A.A.F.R.O., P.O. BOX 601, NAIROBI

Subscription Sh. 5 per volume including postage, payable to the Business Manager, the Government Printer, P.O. Box 128, Nairobi, Kenya. Subscribers are advised to remit postal orders in payment, otherwise bank commission must be added in the case of cheques.

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FERTILIZER TRIALS IN EAST AFRICA

The report on a discussion on fertilizer trials, which is published in this issue, is well worthy of perusal by farmers as well as by technical officers. The main theme running through the discussion was the uncertainty of the results to date and the need for similar discussions at intervals in order that a better over-all picture of the results may be obtained. Responses from applications of nitrogen, of phosphate, and of potash have been found, but the results are not consistent. Perhaps consistency of results should not be expected in a geographically wide area which contains many different soil types, but it had almost been expected that all East African soils would give some response to chemical fertilizers, since their natural fertility is not high.

It seems clear that there are limiting factors to plant growth which confuse the issue in fertilizer trials, and much of the discussion dealt with these. Rainfall is the obvious factor of primary importance, since no amount of plant nutrients in the soil can offset lack of rain at the right time. By grouping the field trials in relation to the annual rainfall of the districts, statistical analysis of the results showed that, on the average, the response to phosphate was greater the higher the rainfall. This was accounted for, in part at least, by the fact that soils in higher rainfall areas (over 50 inches per annum) are usually more acid than those under lower rainfall; and therefore they are more likely to be in need of phosphate. But the point was also brought out that early rains followed by a relatively dry growing season may seriously influence the effect of fertilizers, since these stimulate the growth of the young plant, both in the root system and in vegetative growth, with the result that the plant is more liable to suffer from lack of soil moisture. Several instances were reported of definite visible responses to fertilizers by the young plants, but this was not followed by an increase in yield at harvest. It may be, therefore, that in some parts of East Africa, soil moisture is the real limiting factor, and until the moisture-retaining capacity of the soil is increased no response to fertilizers can be expected except in years of particularly favourable rainfall. Burying the fertilizers in order to encourage deep rooting would help to some extent, but the problem of making better use of the available rain still remains to be investigated.

Our lack of detailed knowledge of East African soils is a serious handicap in fertilizer experiments, since it is patent that we cannot expect all types to react to fertilizers in the same way. Soil surveying is slow work, and it is unfortunate that lack of funds restricted progress in this line during the past 20 years. Mere money will not put this right in a short time, but a team of soil surveyors could greatly assist those who are carrying out fertilizer experiments, even before they are in a position to define and map the soils of an area.

A primary objective in the fertilizer experiments programme for East Africa is to find the best way in which the deposit of phosphate in Uganda can best be used. In the trials under review three forms of phosphate were used: imported superphosphate, unprocessed Uganda rock phosphate, and soda phosphate prepared by calcining Uganda rock with soda from Lake Magadi in Kenya. While the results are far from conclusive, superphosphate seemed to be the most effective of the three, with soda phosphate second and Uganda rock a poor third. It is possible that repeated applications of Uganda rock may increase the content of available prosphate in the soil, but at best it is only slowly available to plants and therefore it is not likely to be economic, except possibly as a long-term investment. Although soda phosphate has not given as high yield increases as has superphosphate, the former does show considerable promise, but its action requires further study and experiment before it can be used with confidence.

Organic manure has given very striking results in the Lake Province, Tanganyika, and the fact that residual effects have been found up to the fifth year after application points to magical properties which, we hope, will be explained in due course in more prosaic terms. It does look like a deficiency of one or more of the minor or trace elements, since the effect lasts long after the organic components must have disappeared, but the possibility was suggested that the effect might be stimulation of microbiological activity, giving more "life" to the soil. It is curious that this striking effect of organic manure has not been found in other parts of East Africa, but it must be remembered that much more experimental work is necessary before generalizations can be made. However, the fact remains that in one district a means has been found whereby large increases in yield (up to 60 per cent) can be obtained, and although this is only a start, it is a very good start.

The interactions between nitrogen and phosphate are interesting, since there is

evidence that either may limit the effect of the other. When nitrogen is added to a soil, it produces an increase in growth (other factors permitting) until a particular ratio of nitrogen to phosphate is reached: above this ratio nitrogen has no effect, but by increasing the phosphate, increases due to nitrogen can again be obtained. Similarly, the effect of added phosphate may be limited by the supply of nitrogen. The critical ratio of nitrogen to phosphate is likely to vary from soil to soil, or even within a soil type, and therefore it would be difficult to find a general guiding figure for fertilizer applications. Further, it is not yet known which fraction or fractions of soil phosphate are active in plant nutrition, and, until this latter problem is solved, it would not be possible to find the critical nitrogen-phosphate ratio for a particular soil. Much work has been done and is being done in all parts of the world on the problem of the relation of soil phosphate to plant nutrition, but no satisfactory solution has yet been found.

Observations in Uganda that nitrate can accumulate in soil under fallow in quantities equivalent to 400 lb. per acre of sulphate of ammonia may explain the inconsistency of results when nitrogenous fertilizers are applied in field trials. The full significance of this nitrate accumulation is not yet understood, but it is evident that a fertilizer experiment on a soil which has a store of nitrate would give conflicting results with both phosphate and nitrogen.

In reading the report of the discussion on fertilizer trials in East Africa, the impression may be gained that the difficulties have been exaggerated, or that the difficulties are so great that results of economic value are unlikely to accrue for many years. It must be remembered, however, that until recently fertilizer trials with food crops have been carried out by officers whose time was largely taken up by other work, and their opportunities for discussion with each other were severely limited. Consequently, the trend of this first East African discussion was to emphasize the difficulties rather than the successes, and it must not be thought that there was any sense of defeatism at the meeting. On the contrary, the posing of problems in a scientific meeting leads to a feeling of optimism, because this leads to a better appreciation of the factors involved. Nevertheless, it was clear that the reasons for inconclusive results must be investigated very carefully, and frequent exchange of views and results will be necessary in order that the best use can be made of the experimental evidence as the work progresses. In the United Kingdom, where fertilizer trials have led to a great change in agricultural practice, field trials have been carried out for the past hundred years, and thus a great mass of experimental data could be correlated in order to frame an agricultural policy. In East Africa we have a long way to go before this can be achieved, but it should be possible to travel at a greater speed by using the experimental methods which have been developed in England through many decades of experience.

There is still some doubt that the soils of East Africa can be made to produce more by direct application of fertilizers to the crop. With some soils it may be necessary to build up the fertility gradually, by means of a long-term fertilizer policy which gives small returns during the first few years. Such a policy would be difficult to apply in practice, since few farmers, whether African or European, can afford to put money into the soil without an immediate financial return from the first crop. Therefore the economics of a fertilizer programme must be watched carefully, and where long-term investment is the only solution the preliminary financial burden would probably have to be borne by the community rather than the individual, by means of loans or other assistance.

Whatever the difficulties, it is clearly of the greatest importance that means should be found of increasing food production in East Africa, particularly in the native areas. If phosphate is the key to success, we have two large deposits, one in Uganda and one at Zizi in the Southern Province of Tanganyika, with sufficient material to satisfy all our needs. But both these deposits contain phosphate in a form which is not available to plants, and some form of processing is necessary in order to make the best use of them. If nitrogen as well as phosphate is required, the plans for harnessing the Owen Falls at the source of the Nile may lead to the production of synthetic nitrogen compounds which can be used as fertilizers. An easy solution to these problems is not likely to be found, but the urgency of increased food production is so great that men and money must be used to the full in the investigational work. But both time and money can be saved by a discussion such as is reported in this number and it is likely that future meetings will show considerable progress in the work.

D.W.D.

THE MAINTENANCE OF SOIL PRODUCTIVITY IN SUKUMALAND AND ADJACENT AREAS, TANGANYIKA

By J. E. Peat and A. N. Prentice, Empire Cotton Growing Corporation

(*Received for publication on 4th July,* 1949)

Introduction and Summary

Information on soil-productivity problems has been gathered over the past decade from the experiment stations of Ukiriguru (18 miles from Mwanza in the broken hill-sand country), and Lubaga (near Shinyanga, 80 miles south of Ukiriguru), and their satellite district plots. As one of us has been transferred to Uganda after ten seasons in Sukumaland, it seems timely to record facts and views, but at the start it should be emphasized that this is in the nature of a progress review.

Sukumaland and some of the adjacent areas have been supporting for generations, and still support, a heavy population. Considering the semi-arid climate and the bad farming, the soils cannot be inherently poor, but the population is rising and the problems of maintaining yield and output have become insistent. Using crop-yield as the yardstick of productivity, we discuss yield as influenced by various treatments on two major soil types of the countryside, a light and a heavy, represented by Ukiriguru and Lubaga respectively. On the deep, light soil there is an appreciable response to manuring, both immediately and residually, the latter being a very important point; on the shallower heavy *ibushi* soil there is a much smaller response. On neither soil are the responses as good as had been hoped from grass-rest or other resting treatments. Both soils, but more especially the heavy, derive marked benefit from tillage by ridging plus tying. On both again a worth-while benefit may show from simple arable rotation. These broad statements of course need modification in detail; and in part should be qualified by "so far as the work has gone". The view we hold in the light of present knowledge is that productivity can be increased by: (*a*) more intensive (and quite feasible) manuring on the light soil, bearing in mind that the light-soil area is in broken country and is interspersed throughout with heavier soils which assist in feeding the light; (*b*) improved tillage on both soils; and (*c*) some rotation of arable crops.

Two soil types other than the main two under discussion get some mention: the black, heavy, low-lying *mbuga,* rich, but erratic in yield according to season; and a hard-pan type *ibambasi* extremely difficult to work but capable of giving heavy yields.

The Background

Sukumaland, roughly a third the size of England, occupies much of the Lake Province of Tanganyika. The Wasukuma tribe numbers well over a million people. The adjacent areas of Musoma District, Uzinza sub-district (an overflow area for Sukumaland), and Ukerewe Island, differ somewhat from Sukumaland, but have many problems or future problems in common. The overall density of population in Sukumaland is probably of the order of 70 to the square mile, but because of the marked maldistribution—even within Sukumaland about half the area is not effectively occupied—much of the countryside has an agricultural population as dense as 200 or more to the square mile.

Agriculture is the main occupation—the gold and diamond mining industries hardly touching the people—and the agriculture is in the hands of African cultivators, there being virtually no European farming. The Wasukuma are a placid people, still cohesive tribally, industrious but short-sighted agriculturists, and skilled in certain directions, although at times a portion of their effort can be misapplied.

The climate determines the broad outline of the agriculture of Sukumaland. Climatically the area is reasonably homogeneous. Association with the word "Lake" Province possibly gives the impression that the climate is softer than it actually is: Sukumaland itself at any rate is what is popularly termed semi-arid. Broadly, the rainfall averages rather over 30 inches for the year, but can vary from 20 inches to 50 inches. The rainy season usually lasts from about mid-October to about mid-May, and planting is normally pre-Christmas. There is in many seasons a "waist" in the rainfall between the two monsoons in mid-season January–February–March. This 1948–49 season for example, admittedly an extreme, the main Ukiriguru planting was in November, but the January–February–March rainfall has totalled only just over 3¼ inches. The within-

season distribution of the rainfall—apart from the chance of the monsoonal gap—is often most erratic, and this constitutes a main farming hazard in Sukumaland. Moisture is often the nutrient in shortest supply. The remaining months of the year are for all practical purposes rainless though heavy showers can occur. Temperature is not generally a limiting factor to crop growth.

The soils vary greatly. In the broken country to the north, e.g. around Ukiriguru, the seeming medley can be sorted out in the light of Milne's conception of a soil-catena into a regular series running from agriculturally light but deep near the tops of the granite hills or ridges to very heavy in the depressions, with several gradations between. In central and southern Sukumaland the countryside is more rolling and the proportion of heavy soils higher, and many stretches, sometimes of hundreds of square miles are *mbuga**.

The Lubaga station is on a dried-out lake bed, and this "lacustrine" soil, an easily worked black loam, *ibushi*, underlain at about two feet depth by nodular limestone, is common in the southern end of Sukumaland.

Two so-called "hardpan" soil types occur: the locally named *itogoro* is very extensive, and could be regarded as a soil-type of position, lying above the *mbuga* and below the upper soils of the catena and is often referred to as "the seepage area": the other, a very hard, deep soil, *ibambasi*, occurs in association with the black loams at the Lubaga end of the province.

The configuration is gentle, except in the broken hill-sand country of the north of Sukumaland and the adjacent areas.

We are much indebted to W. S. Martin (lately Senior Soil Chemist, Uganda) for quick-test nutrient and structure comparisons of local soils. The nutrient status of the heavier soils seems generally good, and the pH is often as high as 8. With the lighter soils typically the Ukiriguru granite derived coarse hill-sands quality must lie to quite an extent in their depth; these sandy loams in continuous cultivation seem to be fairly poor in nutrients and the catena as a whole is mildly acid; but the depth and texture allow of plant resistance to drought; and there is the capacity to recover remarkably quickly from the effects of erosion, given good treatment.

The farming system of the people on the two main soil types, the hill-sands and the black loams—on which we have evidence to offer—is haphazard, but for all practical purposes is one of continuous arable cultivation. Manuring is practised to a very limited extent, under pressure from the field staff. Cultivation is mainly by hand. The practice of making big ridges, which are split annually, is indigenous in the hill-sand country, whilst ordinary "flat" cultivation is the general custom elsewhere.

Bulrush millet and sorghum are the staple food crops. Cassava is important in some areas (and is virtually the only crop to occupy the land for more than a season). Cotton is by far the most important cash-crop. Groundnuts and various pulses are used in inter-cropping and these legumes probably affect the N-balance under continuous cropping.

The Problem

The population is rising. The lightly populated parts of Sukumaland, and of Uzinza, are filling. These virgin areas maintain high yields for some years on occupation—a decade or so?—before dropping to the same sort of level as the older hill-sands country. Even then the "bed-rock" level of fertility when reached need not be impossibly low. In the older areas fertility has already dropped. Fertility, in the restricted sense of nutrient status, plays an important part but by no means the only part in soil productivity, and in the "bad-farming" of the Wasukuma. By "fertility" as a generalization we mean the yield *potential* of the soil for a given crop; by "productivity" the efficiency of usage of what fertility there is, high or low.

The land is certainly being "thrashed" but it stands it amazingly well. *But any loss of soil cannot be borne.* In the *ibushi* areas it is a dead loss for all time; in the light soil areas it is, most luckily, remediable up to a point by toil and thought. Erosion must take priority in the problem. Given this—a pegging of the inherent fertility—the problem is to make the most efficient use of the land. The higher standard of living demanded by the higher population leaves no margin for gross inefficiency. The conservatism of farmers is a natural necessity, but with the Wasukuma it is carried to excess; changes are necessary—an administrative task, and very far from easy—but our part of the work is to show that yields could

* *Mbuga*: a term used widely to mean a heavy and low-lying soil formation or in the ecological sense a seasonally water-logged area carrying a characteristic vegetation, normally grass.

be bettered by means within the capacity of the peasant himself.

The Indicator Crops

The main crops with which we are concerned in the north of Sukumaland are bulrush millet and cotton. At the Lubaga end of the country millet is replaced by sorghum. Bulrush millet is a crop which fits in well to the soils and climate, and the present general level of fertility. It is used on Ukiriguru as the standard grain indicator crop of yield. At Lubaga, following the custom in the surrounding district, sorghum is the grain indicator.

Cotton is the other main indicator crop, on both stations. Cotton has been well described as "tough stuff", and although it has its numerous pests and diseases, if given anything like a chance it is on the whole well suited to Sukumaland, having the capacity to thrive—as shown over a decade by the yields on Ukiriguru and Lubaga and the district plots—probably as well here as anywhere else in Africa where it is a rain-fed crop. It is at least fair as an indicator, and looms so large in the economy of Sukumaland, and so much work is done on it in other directions on the stations, that it is only natural to use cotton in agronomic experiments. Much of the work of the stations "stems", as the Americans have it, from cotton. An interested body such as the Empire Cotton Growing Corporation, staffing stations in collaboration with territorial departments, has been the first to say that cotton must not be treated as a crop apart but must take its place in the farming scheme of things; and the cotton-breeders (as we happen to be) saw very early in the work that the most highly bred variety would not help if the soil was disappearing, or the fertility dropping, or the grower short of food; and so in the absence of anyone else the cotton breeder had to be his own agronomist.

The Experimental Evidence: and Discussion

Manuring on the hill-sands with farm yard manure (FYM) or compost betters the yield appreciably in the year of application, which is to be expected, but the benefits also carry on in the following or first residual season, in the second residual season, and in the third residual season—in general at levels less than the responses in the year of application but still very good. At Ukiriguru, fourth-year residual responses will be measured this season—the fifth season after application. Figures from two of several four-year trials largely tell their own story: (there may be some partial rotation complication, better grown cotton following manuring possibly having a greater rotation effect).

UKIRIGURU HILL SANDS

Yield Compared to No-manure: Control = 100

Year of Effect	Table A: Manuring Rates: 7 tons per acre	Table A: Manuring Rates: 3 tons per acre	Table B: Manuring Rates	Table B: Manuring Rates: 5 tons per acre
Direct Application:				
Crop: Bulrush Millet ..	147	118	Crop: Bulrush Millet	162
1st Residual Response:				
Crop: Bulrush Millet ..	136	110*	Crop: Cotton	140
2nd Residual Response:				
Crop: Cotton	126	105*	Crop: Bulrush Millet	161†
3rd Residual Response:				
Crop: Bulrush Millet ..	135	117	Crop: Cotton	134

*Not significant. †Exceptional.

This prolonged and marked residual benefit from manuring is of the highest importance in a system of continuous arable cultivation, and must be considered against other methods —e.g. land-resting—of raising and maintaining productivity. There seems little reason to doubt that results from Ukiriguru apply to similar soil-types elsewhere in Sukumaland.

The results from compost and FYM are very similar. (Some of the Ukiriguru cattle are bedded down in a covered yard and FYM made; the remainder are bedded in open *bomas* on the hill and open-pen rainy season compost made.) Both organics have been used in a number of experiments on Ukiriguru, and in general they give the same style of responses, whether on cotton or millet, direct or residual. "Manuring" in this article therefore means organic manuring by either compost or FYM. The optimum rate of application of manure has not been tested in detail but a three-ton dressing has smaller direct and residual effects on yield than has a five-ton dressing, and we take five tons per acre as a convenient working basis for normal non-experimental field work. Ukiriguru is fairly large as experiment stations go. The level of yield on the bulk

fields is good on an absolute standard, and often a multiple of that over the fence where manuring is desultory if practised at all. Manuring at five tons an acre every fourth year would appear to keep the hill-sands in reasonable "heart". In practice, with many fields under experiment, the station as a whole is not on a hard-and-fast four-year manuring routine, but this could be fully practicable. The immediate question is, would it be equally practicable for the native? The answer broadly would seem to be yes.

A third or more of the householders in many districts own no cattle, but an indigenous system of borrowing on a keep-for-products basis seems well established and universal. Quantitatively, the average homestead could produce enough manure for roughly a quarter of the six acres of the hill-sands portion of the holding every year. The ten cattle or so—or a correspondingly bigger number of small stock—of the hypothetical homestead, kraaled at night only, could turn the spare residues from the crops into about seven to eight tons of manure. A recent duplicate test at Ukiriguru showed that ten very ordinary beasts in five months, kraaling only at night, turned half the stalks from five acres of medium-poor millet (1,200 lb. per acre used, allowing half for domestic fuel consumption) and from one acre of inferior cotton, into seven and a half tons of manure. The quantity is probably conservative; and of course, taking the year through, even although the crop residues are finished after half the year, the beasts are still producing dung during the other half. Night kraaling of cattle is universal throughout Sukumaland, the stock being driven into open thorn-fenced *bomas* for protection against hyenas and the like, and to stop indiscriminate roaming through crops when unherded in this fenceless land.

To make this amount of manure means more work for the people in carrying the straw residues to the *bomas* (instead of letting cattle graze them in situ); otherwise, the end-product is a small quantity of desiccated "*boma* manure". This extra work should be fitted in after harvest without much dislocation of the agricultural year. What the stubble fields are losing through not having the stalks grazed in the field, the present almost universal practice, is unknown. We have to assume that the orderly making of manure is the much more efficient practice. The native has to be pressed to apply to the field even his present negligible tonnage of "*boma* manure". With seven to ten tons to apply, the work would be considerable, but by no means impossible.

It must largely be a matter of timing: getting the manure to the edge of the cultivated area soon after harvest and applying at the time of the first land-preparation. At Ukiriguru some tests of the labour requirements have been made. With an average travel from boma to field of about one-third of a mile, about three-quarters of a ton daily can be transported to the field edge by a donkey using cheap home-made panniers or Zanzibar packs. The pack-ox idea, excellent in theory, has never caught on in native practice so far, but there seems to be no aversion to using donkeys where they are available. Once the manure is heaped at the side of the field it has to be carried by baskets and spread, and at Ukiriguru a woman or juvenile can deal with this operation at the rate of a ton per 6-hour day. Thus the potential manure-production of the average holding could be transported to the field in under a fortnight at a comparatively slack season, and applied to the field at the right time in a few days.

Analyses of the Ukirigruru FYM and Compost (kindly carried out by the E.A. Agricultural Forestry Research Organization Fertilizer Team) show for the season tested, on an air dry basis: Farm Yard Manure 1.5 per cent N. and 0.69 per cent P_2O_5: and Compost 0.93 per cent N. and 0.52 per cent P_2O_5. The straight nutrients value could account for the effect in the year of application, but the main interest lies in the continuing residual responses. The pointers are that phosphate is the nutrient predominantly concerned in these responses. Factually, enough of the land that responds can be manured sufficiently to keep up its productivity under continuous use. It seems that the system in the hill-sands type of country should hinge on the fact that cattle are present in any case, and do well, and that the Peter of the rich low lands may be robbed by the cattle in part to pay the Paul of the high.

It is convenient here to digress to discuss briefly some aspects of cropping on *mbuga*. These heavy black soils, though they produce fat dividends in the good years, are much more tricky to crop than are the sands in years of drought and years of patchy planting rains and also in very wet years. In some years it may be very difficult to establish, and in others to carry through, crops on the heavy soils, whereas the crops on the deep sands make at least a reasonable show. In the very wet years the heavy soils become water-logged while the

sands on the whole do not. Mz. 561 cotton planted in the Ukiriguru *mbuga* in 1941-42, water-logged and attacked by Capsid (Lygus), yielded at the rate of 300 lb. seed-cotton per acre. In the *mbuga* the next year, a favourable year, the yield of Mz. 561 was 1,680 lb. per acre. In 1946, another very favourable year, *mbuga* Mz. 561 yielded 1,490 lb. per acre, and the following year, the wettest on record, 220 lb. per acre. In contrast on the hill "exhaustion" plot unmanured but tie-ridged, but probably fairly near bedrock as regards fertility, yields for these four seasons were 550, 820, 780 and 380 lb. per acre. The sorghum yields in the *mbuga* can be erratic. In some years the early maturing sorghums suffer; in others the later maturing types. In good years the yields from *mbuga* areas can be very good. For full advantage to be taken of these areas there must be food and seed storage to tide over the difficult years.

To return to manuring, the black loams at Lubaga show a much smaller direct and residual response to manuring than do the Ukiriguru hill-sands. The inherent fertility of the run of the black loams is good, and not ephemeral. An acre has been kept under continuous (annual) cotton at Lubaga, with everything carted off except the roots and nothing put back, to see how long it would take to show signs of "exhaustion"; the absolute yield level is not remarkable for the black loams, but the plot, now in its fourteenth year, beat its own record last year with 815 lb. seed-cotton per acre. A change was made from flat to tie-ridge cultivation seven years ago, and the original strain of cotton was also changed to a more productive one, but the point is that even though the yield potential may have been allowed to express itself more fully because of the changes, there is still no apparent falling off in yield. A sister plot under sorghum tells very much the same story: the yield of grain in the last two years at an average of 960 lb. per acre has been slightly above that of the first two years. The intervening years show great fluctuations in yields, no doubt connected with seasons and pests, but certainly no downward trend can yet be adduced. The black loams might be expected to show no spectacular response to manure or fertilizers, and this is confirmed by the experimental evidence. A set of trials in a representative field over six seasons has given results which can be expressed as crude averages thus:

YIELD COMPARED TO NO-MANURE, CONTROL=100

Manuring at 5 Tons Per Acre	Sorghum	Cotton
Direct Responses ..	117 (5 years av.)	119 (6 years av.)
1st Residual Responses	108 (4 „)	113 (5 „)
2nd Residual Responses	106 (2 „)	109 (3 „)

The yield of the unmanured grain controls varied from a lowest of under 400 lb. per acre grain to a highest of over 1,400 lb. with an average of 920 lb.; those of the cotton controls from a lowest of 182 lb. to a highest of 1,260 lb. with a 6-year average of 610 lb. seed-cotton per acre.

Fertilizers.—Fertilizer experiments on Ukiriguru have been under way for too few years to draw rigid conclusions. Potash can probably be dismissed as having no effect. But it might be mentioned, as indicative of the need for caution in applying local results too widely, that at one station in the adjacent Western Province this past season potash gave a substantial beneficial effect as did phosphate, and the phosphate-potash interactions were striking. (Communication from Provincial Agricultural Officer, Western Province.)

Soda phosphate has been tried at Ukiriguru, in common with many other centres in East Africa, and here the results so far have shown moderate benefits, 10 per cent the one year of appplication on cotton, and 18 per cent on a very poor millet crop the other year of application. From this present season's results there are worthwhile soda phosphate residual benefits from this trial—of the order of 20 per cent, the crop being good-yielding cotton. And this season, in one trial, from a dressing of 300 lb. per acre of single superphosphate there is an increase over control of around 500 lb. seed-cotton per acre—about a 70 per cent increase. It now seems probable that phosphate is playing the predominant part in the manurial responses being obtained.

Nitrogen as sulphate of ammonia, 100 lb. per acre applied at planting, bettered the yield of a poor crop of bulrush millet by a significant 35 per cent in a wet year, and the yield of a good crop of cotton by 7 per cent in a dry year. There were no interactions with phosphate. The results now being gathered over the whole area by the recently organized E.A. Agricultural Forestry Research Organization Fertilizer Team will help to throw light on fertilizer problems. The team is working with food-crop indicators; Ukiriguru is continuing NPK plus organic trials with cotton as the indicator.

Cultivation methods.—The general order of "natural" yields on the hill sands of Ukiriguru is, in very round figures, 600 lb. per acre for seed-cotton and 450 lb. per acre for bulrush millet. This is on land that is deliberately not manured and not rested, but which on the other hand is reasonably managed in respect of time and efficiency of cultivation, planting, spacing and weeding.

The traditional method of cultivation at this end of Sukumaland is the large ridge, about five feet between crests. This method is excellent when properly carried out. The deep digging of necessity involved is probably the very treatment wanted by this particular soil, although more evidence is still wanted on this point. In land levelling at Ukiriguru, converting native cultivation into areas suitable for station work, there is a working of the land which for many soils would constitute "soil abuse". But on the hill-sands the cropping for the next period of years seems to have benefited by the soil stirring. The splitting of the ridges every year means deep burial of weeds. That it would be wrong to omit splitting as an operation has been shown by Ukiriguru experiments. Final yields on a millet crop, with the treatments "split" and "non-split" ridges, were not significantly different, the "non-split" catching up after a shaky start: but there was a marked depression of growth in the earlier part of the season. A recent similar experiment with cotton showed a significant difference, the ratio "split" to "non-split" being 177:100. In native practice the ridge is split annually. Ridging lends itself to farming approximately on the contour once the right start has been made, and there has been considerable success in enforcing this measure of conservation. But, generally, native practice differs essentially from that of the station in having less well-made ridges and in leaving the ridges untied.

Tie-ridging is the making of ties—small earth barriers or cross-ties—between the main ridges, at about three-pace intervals, leaving the land in a series of rain-holding basins. Tie-ridging, if well done, holds all the rain that falls; by the same token it is a complete check on soil erosion by water. The hill-sands are of good permeability but even so cannot hold everything during the ordinary rains, let alone the torrential storms experienced in semi-arid Africa; and no matter how nearly perfect the alignment of the main ridges, some of the water runs off with some of the best of the soil, some of the humus and the finer fraction, leaving the coarser sand particles behind. Tying completes the process started by proper alignment of the parent ridges; tie-ridging is the only method of erosion-control used or necessary (apart from the problems raised by station roads) on Ukiriguru, where every acre of the hill-sands is thus treated.

At Ukiriguru the poorer and non-tied native cultivators' ridges have been tested against station-style tied ridges on various occasions. The results are given relative to "native method" = 100 for ease of comparison:

Year and Crop	Native Ridges, Non-Tied	Station-Type Ridges, Tied
1947—		
Cotton ..	100	152
Bulrush Millet	100	104*
1948—		
Cotton ..	100	116
Cotton ..	100	120
Maize	100	134

*Not significant

The results represent on the average a benefit well worth having from better ridging with tying, an unequivocal gain in productivity. The benefit is not so large as on the heavier Lubaga-type soils, presumably because the extra moisture held by the tying is even more important to the less permeable soils than to the hill-sands.

The paramount need of the black loams at the southern end of Sukumaland is conservation of soil and rainfall. The topography is gentle, but the black loam is highly susceptible to erosion by wind and water, and is impermeable or retentive enough to make water-supply to the plant the limiting factor to growth in many seasons. Ridging and ridge-tying provide the dual conservation admirably. Results up to 1946 (A. N. Prentice: E.A. Agricultural Journal, Vol. XII, p. 101-108) showed that on the typical black loam at Lubaga the customary "flat" cultivation of the district yielded usually considerably poorer than cultivation on tied ridges; the crude average of eleven experiments over seven years (crops mainly sorghum and cotton), showed a benefit of the order of 100 per cent from tie-ridging. Four further trials on this soil in 1947 and 1948 happened to be with indicator crops other than sorghum and cotton, and they show a comparatively small but by no means unimportant benefit from tie-ridging; 1947 was an exceptionally wet year with a good distribution of rains; 1948 a medium-poor year but with exceptionally good late season rains:

	Pounds per acre		c.f. Flat=100
	Flat	Tie-Ridged	
1947—			
Bulrush Millet ..	1,400	1,300	100 : 93*
Groundnuts (Unshelled) ..	1,570	1,925	100 : 123
1948—			
Maize	2,022	2,320	100 : 115*
Groundnuts (Unshelled) ..	1,000	1,590	100 : 159

*Not significant

Crops might be expected to react differently within limits to tie-ridging according to their different water requirements and possibly other characteristics. The policy of strongly recommending tie-ridging has been adopted and carried out vigorously in the past few seasons on the suitable soil-types in the districts. Cotton and cassava are the crops on which attention has been concentrated for a start. The immediate yield-responses are appreciated. The Provincial Agricultural Officer, Lake Province, in one of his monthly reports stated that in one part of Mwanza district two tied ridges of cassava were being sold for the price of three not tied. And with cotton on its present wave of popularity tie-ridging can be laid down as a conditional permission of acreage. But with millet, agreeing with trial-results on the stations, the immediate benefit seems generally smaller, and only a little tie-ridging has appeared in the grain crops. As with manuring it will probably be necessary, by sheer repetition of propaganda and enforcement, to get the people into the habit of using a method over a number of years before it can be said to be influencing their agriculture markedly. In the long run, of course, the indirect or negative help, the preventing of erosion, is of the greatest importance. No other method we know gives the complete protection afforded by tie-ridging against water-caused erosion on arable land. The ridging of land, without tying, affords inferior protection. The extra labour needed to tie is not unduly great: at Ukiriguru, with hand labour, it takes four men-days to make the ties on an acre, as against four men-days per acre for the pulling of the weeds into the furrows preparatory to splitting the ridges, and 17 men-days for the re-building of the parent ridges. At Lubaga, ox-drawn implements have been successfully adapted by Mr. J. T. Purvis for the making of ties on land previously ridged by plough, and an 8-ox-draught machine can tie at least a 5-acre field in a day.

Land resting.—It had been hoped that short cycle grass-rests grazed throughout the resting-period could be the solution to some of the problems for the hill-sands. However, the results obtained so far are on the whole disappointing, and in part confusing: much in the resting-crop picture is still far from clear and "following-up" work is in progress.

As far as the resting crop work has gone on in Ukiriguru, the effects in the first year after treatment are that the yields of millet or cotton are pushed up considerably. In four trials, after Elephant Grass rest for three years, grazed at intervals or grazed only before digging in, the first post-rest crops, bulrush millet, were on the crude average yielding some 35 per cent better than the continuously cultivated controls. In three of the four trials, however, the second-year benefit, with cotton as the indicator crop, was negligible; but the fourth trial showed a continued benefit not only in the second but in later years. Another trial seemingly showed a recovery in the third year (crop, bulrush millet) only to drop back again in the fourth (crop, cotton). This is rather confusing, especially by contrast with the fairly clear-cut residual responses from manuring at Ukiriguru, and the responses from ridge-tying at Lubaga. Rests longer than three years have not yet been used in trials.

At Lubaga the effect of a 3-years' grass rest also is not—to the evidence so far—as large as had been hoped. Crumb-structure has fairly obviously been bettered, although no figures are yet available. As at Ukiriguru, following the lead of Uganda, the earlier grass-rotation experiments had Elephant Grass as the standard. Three years of rest under the grass were followed by three cropping years; the post-grass crop-yields compared with controls which were continuously cropped for the six years, were:

	Indicator Crop Cotton		Indicator Crop Sorghum	
	Control	Post-Grass	Control	Post-Grass
1st year ..	100	98	100	107
2nd year ..	100	120	100	117
3rd year ..	100	104	100	112

The explanation of the absence of any real difference in the first year's results was possibly "indigestion" in the post-grass plots in an exceptionally dry year: the stalks were either grazed or burnt off. The second-year differences although comparatively small were real.

In the third ear the effect of the rest seemed to be fading but was still significant with the sorghum indicator. In a further trial, including resting treatments of both Elephant Grass and *Cenchrus ciliaris,* the first cropping year was exceptionally wet—for what the fact is worth—and these post-grass treatments showed significant increases of the order of 40 per cent and 50 per cent over the control; unfortunately the second-year results of this particular trial were spoilt by mistakes at harvesting; the third year results are awaited.

The evidence on how big and lasting is the "fertility" gain from grass-rest, as measured in cropping responses, is admittedly scanty, but present indications are that the results would hardly justify the trouble of making a major change to a new agricultural system. The difficulties in establishing good grass in Sukumaland are very real; but a fairly good cover can be established in the end, and is well worth holding for as many years as it remains good. The "tumbledown" fallow, on what little evidence there is so far, seems to be no answer: a "tumbledown" fallow on the long-cropped hill-sands gives the most miserable natural cover even after three years, and the first season post rest effect on this year's showing—admittedly a droughty difficult year—with cotton as the indicator crop, seems to be in parts actually a depression of plant growth compared to continuous unmanured cultivation. *Tridax repens* was a major constituent of the "tumbledown" fallow and came up freely in the young cotton. This may have been one of the influencing factors.

The establishment—or re-establishment—of the better grasses in the black loam countryside would certainly do a great deal to making more efficient use of that land. At Lubaga pastures of *Cenchrus ciliaris* have been heavily stocked and yet the cattle have not been able to get on top of the grass. The optimum stocking rate cannot yet be detailed, but it promises on well-established paddocks to be of the order of beasts per acre for the year as a whole, instead of acres per beast as on the unimproved pastures. The black loam country, which occurs in great unbroken sweeps, is apt to become a Black Country in a dry season of high winds. Overgrazing of the natural pastures is an even more potent cause of dust-storms than trampling of the arable. Planted pastures can confidently be expected to improve on the natural pastures in this respect of soil-cover.

The search for better grasses—and, incidentally for pasture legumes, though this without success so far—is a part of the work of the stations, running concurrently with some work on establishment and management. Sukumaland is essentially short-grass country, and after the natural phase of following Uganda and using Elephant Grass (*Pennisetum purpureum*) in the earlier work, some of the local grasses were found to have value. Experiments on the Stations are now using one of, or a mixture of, three local pasture-grasses, *Cenchrus ciliaris* (African Foxtail) *Chloris gayana* (Rhodes Grass) and *Bothriochloa insculpta. Chloris gayana* from Serere (Uganda) is as promising as any of the Tanganyika ecotypes tried so far. *Bothriochloa insculpta* is one of the commonest of the good grasses occurring throughout Sukumaland. *Cenchrus ciliaris* has the fundamental merits of marked drought resistance and persistence, extremely quick flushing after rain, high yield and a notable ability to survive and even thrive on an intensity of grazing which would kill off most other grasses; its palatability is at least fair, its feed-value high and its seed-production rate fair; its fault lies in its habit of becoming tufted and running to heather-like stems if it gets away from the grazing beast. The grass is not naturally common, but the Lubaga end of Sukumaland seems to be a centre of variability, and promising forms have been isolated. Some of these may be the answer to the question of improving the habit, but improvement may also be got through the correct management of the grass, knowledge of which is being slowly acquired from experience and experiment.

Rotation.—Simple rotation of cotton and sorghum in itself seems to be giving a gain in the yield of either crop as compared with no rotation. The layout of the trials (until now) has not been such as to test how long the effect might last beyond the first year of simple rotation. A trial at Lubaga which has run for six years has included the treatments, continuous cotton and continuous sorghum, besides those of cotton-after-sorghum and sorghum-after-cotton every year (except the first, of course). The crude 5-year average puts the rotated cotton 13 per cent above the continuous cotton (results mainly non-significant singly) and the rotated sorghum 25 per cent above the continuous non-rotated sorghum (significant). The Ukiriguru experience on the hill-sands is that, at least in some seasons, bulrush millet yields are better by up to 20 per cent when following cotton than when following millet; the corresponding effect of millet on cotton seems smaller, if present at all.

At Ukiriguru, land for three seasons under cassava allowed to go weedy after the first season, when opened to cropping showed, in the first cropping season with bulrush millet, a 32 per cent increase in yield compared to the control continuous millet; and a second season 13 per cent increase over control with cotton as the indicator crop.

This contribution that rotation can make to productivity must certainly not be disregarded.

The "Hard-pan" Soils.—An interesting soil type, a hard-pan, is worth mention. Hard "pan" may be a misnomer as it is for all practical purposes hard to depth. A little of this occurs on Lubaga. It is moderately extensive in the southern parts of Sukumaland, but in spite of land hunger is comparatively little used as it is exceptionally difficult to work and is the first soil to suffer in a drought. Once a stand has been established—no simple matter—the secret of cultivating this soil seems to be nothing but the holding of water; and tie-ridging, seen at about its most spectacular on this soil, takes care of this and erosion. The tie-ridging seems to work mainly if not entirely through the chance it gives to more of the rain to soak in than can happen on a flat surface. Deeper digging than usual of the "flat" plots has been tried, to simulate the amount of stirring given to the tie-ridging plots by the nature of the operation, but "deep-dug flat" shows little if any benefit over "ordinary flat". Cotton over the last four years has shown big percentage yield increases from tie-ridging:

	Flat	Tie-Ridged
1945 ..	100	180
1946 ..	(Failure, due to insect attack: potential difference as in other years)	
1947 ..	100	172
1948 ..	100	154

The sorghum story is similar, but insect attack meant that straw weights instead of grain had to be used in two years out of four; the crude 4-year average was 100: 198, flat: tie-ridged.

It was anticipated that an unusually wet season might lead to water-logging and a depression of the tie-ridged yield, but 1947 was an exceptionally wet year, and although mid-season water-logging was certainly apparent in the look of the crops, the end-result speaks for itself. The actual yields (from areas totalling nearly half an acre per treatment) were at the rates of 1,100, 1,110 and 1,470 lb. seed-cotton per acre in the tie-ridged treatment in the years of the table. Such yields can stand comparison with those of rain-fed cotton anywhere. The sorghum yields in the two years that gave grain were 710 lb. per acre (very ordinary) and in 1948 the exceptionally good figure of 2,600 lb. per acre. The inherent potential of this soil seems to need just water to release it. Manuring was tried on split plots at the comparatively heavy dressing of 10 tons per acre but gave negligible increases. Only one sub-type of this specialized hard-pan has come under experiment but the possibilities seem well worth further work.

There is very little knowledge about the other hard-pan types, the great *itogoro* class. There are great stretches of undulating *itogoro* and *itogoro-mbuga* soils in the centre of Sukumaland, where they are probably the predominant soil-type. The nutrient status appears to be at least fair, and they will probably benefit from ridging and tying where not naturally too wet. How they would respond to any treatment, however, is still mainly guess-work.

THE EFFECT OF ANTRYCIDE ON T. VIVAX IN TSETSE FLIES

By E. Aneurin Lewis, Department of Veterinary Services, Kenya

(*Received for publication on 25th July*, 1949)

There are a number of approaches to the control of trypanosomiasis transmitted by tsetse flies. The fly population may be reduced or eliminated by bush-clearing; animals on which the tsetses normally and principally feed may be removed from the fly-infected areas; hand-catching and trapping are useful anti-tsetse measures which have been successful in some places; and the application of insecticides is a more recent direct method of attack on tsetse flies. The disease caused by trypanosomes in man and animals can be controlled, to some extent, by the administration of medicinal compounds or trypanocides. The trypanocidal drugs either destroy or suppress the trypanosomes with which man or his domestic stock is infected, or they may so modify the virulence of the parasites and the course of the disease as to enable the patient to recover and survive. The drugs hitherto issued are claimed to have curative properties and a few seem to confer some degree of protection for a month or so. The newly discovered Antrycide is believed to protect cattle against infection or re-infection for a longer period or to enable cattle to survive for months in the presence of infected tsetse flies. The tendency of trypanosomes acquiring a resistance to drugs is a danger always to be borne in mind.

The prophylactic value of Antrycide rests not only on the more or less immediate lethal effect of the drug on the trypanosomes in the treated animal, but also, apparently, on the gradual absorption of the chemical deposit and its residual effect over a relatively long period. The trypanocidal properties of this drug, its gradual absorption into the blood stream, and its consequent continued presence in the system of treated animals raise the question of its effect on the trypanosomes in infected tsetses that feed on animals to which Antrycide has been administered as a protective measutre. Does the Antrycide in the blood taken up by the tsetse destroy the trypanosomes with which the fly is infected? Does it help in the control of trypanosomiasis by sterilizing the tsetse vectors of the disease?

The prospect of rendering the tsetse harmless by the use of trypanocides has been entertained by a number of colleagues with whom the writer has discussed the control of trypanosomiasis; and as Antrycide is said to be retained in the treated animal sufficiently long to feed tsetses on many occasions, it was considered suitable for the tests which are described in this article. Furthermore, a virulent (Emali) strain of *Trypanosoma vivax* in *Glossina pallidipes* was available for tests at the Veterinary Research Laboratory, Kabete. This strain has been maintained by passage from cattle to tsetse and from tsetse to cattle for several years. It is highly pathogenic to cattle. The trypanocidal effect of Antrycide on the trypanosome in the fly, or a change in the virulence of the trypanosome transmitted by the fly could be determined by close observations at the laboratory.

Random tests were made with known infective *G. pallidipes* which had fed on cattle treated with Antrycide in experiments conducted at Kabete by Dr. D. G. Davey of the Imperial Chemical Industries, England. These experiments were to test the value of the drug as a curative and prophylactic to trypanosomiasis in stock. The effect of Antrycide on trypanosomes in the fly was considered to be of less importance. At the conclusion of the experiments, six *G. pallidipes* which had fed on two or more occasions on treated cattle were put to feed to repletion on four clean oxen. The flies transmitted the disease —provoked by *T. vivax*—to each of the beasts. Two of the reactors recovered. Two died in 14 and 19 days respectively after having been bitten; and the symptoms were typically those of an acute and virulent form of *T. vivax* infection.

The feeding of these flies was not closely observed, and one or more may have had only a small meal of blood on a few days. The amount of Antrycide in the blood may have been insufficient to affect the trypanosomes in the proboscis of the tsetses, and even one unaffected fly would have transmitted the normal disease to the clean cattle. It was therefore considered desirable to repeat the test so planned, in this instance, as to ensure the maximum amount of Antrycide for each fly. Only those flies which had fed to repletion for the requisite number of times on a bovine previously dosed with the recom-

mended quantity of Antrycide were used for transmission of *T. vivax* to clean or susceptible cattle.

Twenty *G. pallidipes* whose saliva (obtained by the "probe" method) had contained infective forms of *T. vivax* for periods ranging from 3 to 16 days were fed to repletion every other day on an uninfected ox No. 3608. Each fly fed three times in six days. The first feeding took place a day after the ox, weighing 177 lb., had been injected subcutaneously with 0.75 grams of soluble Antrycide (dimetho-sulphate). The second and third meals were taken during the following five days.

The twenty flies were then fed once on a clean ox, No. 4585, in blood smears of which *T. vivax* appeared ten days later. The temperature rose gradually from 101.8°F. on the ninth day to 104.0°F. on the twelfth day (*see* chart), and thereafter returned to normal with a few exacerbations periodically. Parasites* were present, in varying numbers daily, from the tenth to the twenty-third day after which they were scarce or absent. Ox No. 4585 survived the infection.

The flies were transferred to ox No. 3608 for another meal of Antrycide-containing blood; and, two days later, on to bovine No. 1980, a clean ox. This bovine also reacted to bites of the tsetse, on the ninth day. The temperature remained at about 104.0°F. for six days; and *T. vivax* was common in the blood up to the sixteenth day when the animal died of an acute and virulent trypanosomiasis.

Five *G. pallidipes* died. The remaining fifteen were now fed on five consecutive occasions on the treated animal. For the next meal, one fly was put on ox No. 3606, which reacted to an acute infection by *T. vivax* and died fourteen days after the single bite. Another bovine, No. 2870, was also bitten by one fly. This animal did not contract trypanosomiasis although the saliva of the fly which fed on the beast showed, previously and subsequently, mature infective forms of *T. vivax*.

The tsetses, up to this stage, had obtained nine full meals of blood from the Antrycide-treated ox. The colonies of developmental forms of *T. vivax* in the labial tube (*see* Figs. I and II), through which the tsetse draws up the blood, had not been destroyed; nor had further development to mature infective trypanosomes been obviously affected. Nevertheless, the test was continued; and the flies, now seven in number were fed on the treated bovine on ten consecutive occasions. Finally, four of the flies were fed singly on four different beasts; and a group of three *G. pallidipes* was put to feed on another ox.

The beast (No. 7241) on which the group of three flies were fed reacted and died in 24 days. Three others (Nos. 7319, 7330 and 7735), on each of which one fly had fed, contracted trypanosomiasis and died of an acute disease in 15, 16 and 24 days respectively (*see* charts). Bovine No. 7230 broke its leg, and was destroyed.

The seven *G. pallidipes* alive at the end of the feeding tests had obtained nineteen full meals of blood from the animal treated with Antrycide. They had fed, usually on alternate days, for a period of 41 days, which is believed to be about the longevity of a tsetse fly under natural conditions. It will be noted (*see* Table I) that *G. pallidipes* in the laboratory live for longer periods, and that the specimens used in the investigation had emerged from pupæ 10 to 34 days before their first feed on ox No. 3608 which had been dosed with Antrycide. The figures in the first column of the Table also represent the number of days taken for the development of *T. vivax* in the tsetses which were fed on an infected bovine soon after the flies "hatched" out. The numbers of full meals (5 to 19) taken by other *G. pallidipes* in the test described are given in the third column of the Table; and the ages (36 to 38 days) of the flies are shown in the last column.

Another, smaller, lot of *G. pallidipes*, reared under the same conditions and infected on the same bovine, was fed on animals not treated with Antrycide. They were used as a control to the other group of twenty flies, and for the transmission of *T. vivax* to five cattle for comparative study. Three of these cattle (Nos. 5946, 6994 and 5948) died of acute *T. vivax* infection in 16, 15 and 16 days respectively. One (No. 3842) contracted the disease and recovered. The fifth (No. 5524) did not become infected by a single bite of a fly in the saliva of which, examined before and after this particular feed, there were mature infective forms of *T. vivax*.

No difference was discernible in the reaction to *T. vivax* infection transmitted by flies which

*The number of parasites counted in 500 "microscope" fields (using a 10x eyepiece, and a 1/12" oil immersion lens) of a blood smear is shown immediately below the horizontal top border of each graph.

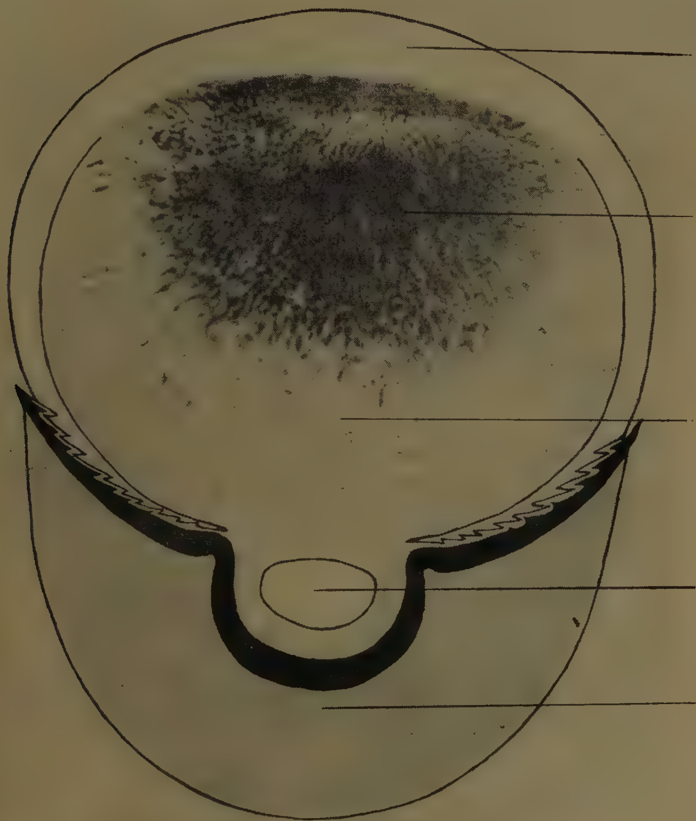
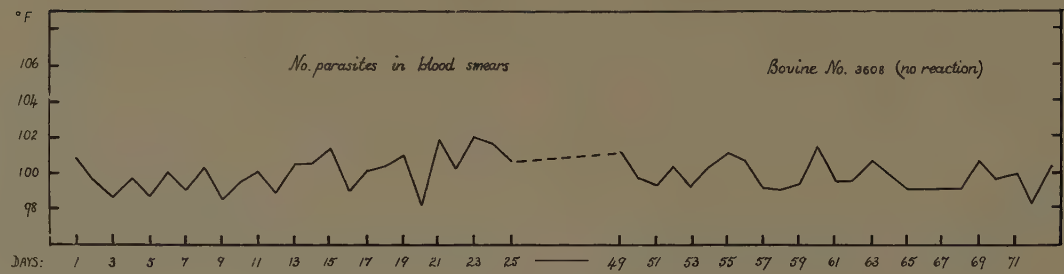


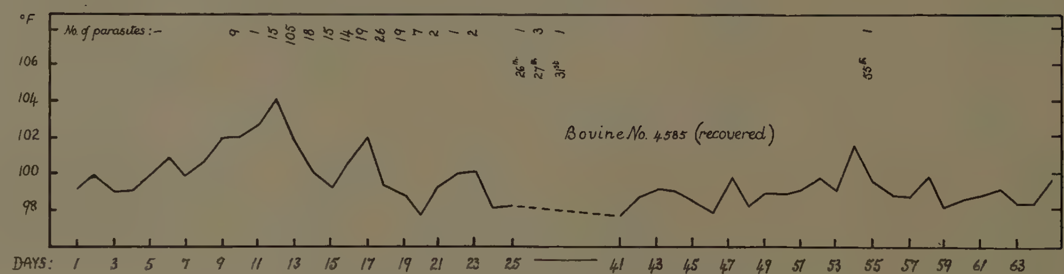
FIG. 1.—A transverse section (diagrammatic) of the proboscis of a tsetse showing the inner tube, and the outer tube containing a cluster or colony of *T. vivax*.

FIG. 2.—Photograph of a portion of the proboscis of a tsetse illustrating two clusters of *T. vivax* in the labial cavity (outer tube).

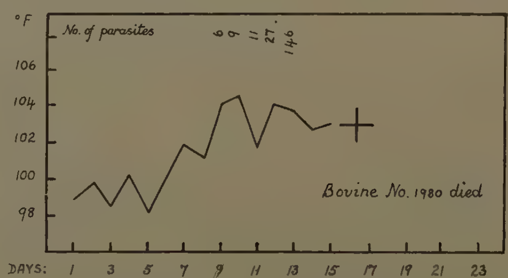
THE EFFECT OF ANTRYCIDE ON *T. VIVAX* IN TSETSE FLIES



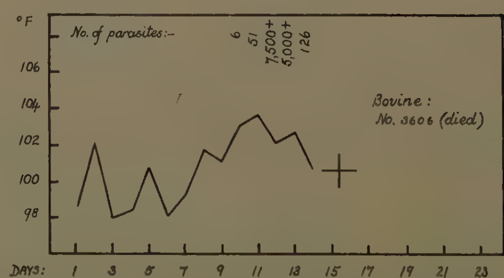
Antrycide-treated bovine No. 3608 did not react to 280 infected bites of tsetse fed over a period of forty-one days.



Reaction of bovine No. 4585 to bites of 20 infected flies fed in one day

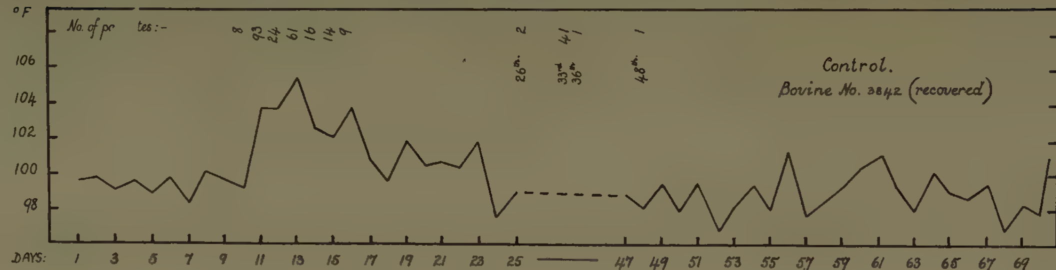


Bovine No. 1980: bitten by 20 infected flies in one day

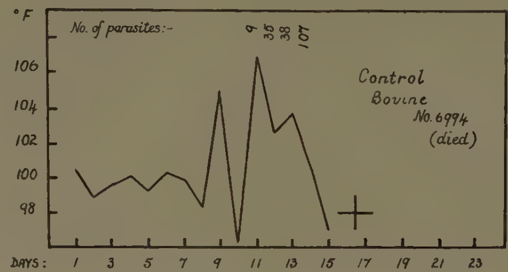


Bovine No. 3606: bitten once by one infected fly

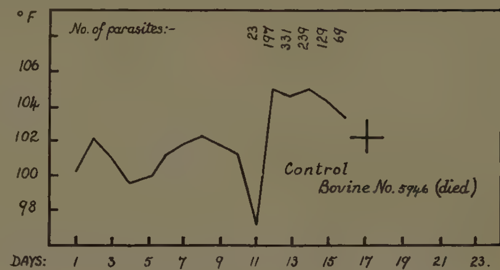
THE EFFECT OF ANTRYCIDE ON *T. VIVAX* IN TSETSE FLIES



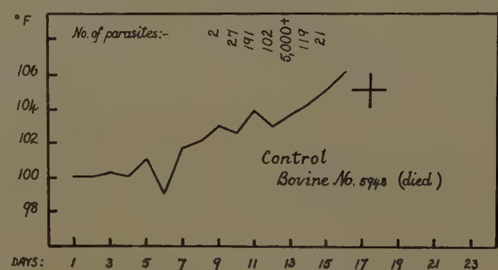
Reaction of bovine No. 3842 to 24 bites by 3 infected flies fed 8 times



Bovine No. 6994: bitten once by one infected fly

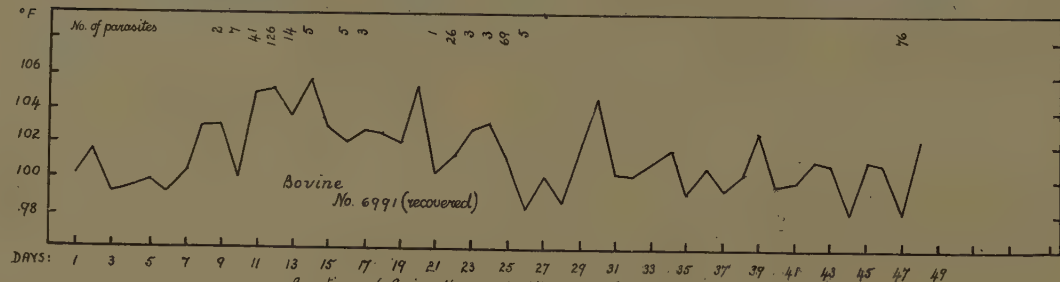


Bovine No. 5946: bitten once by one infected fly

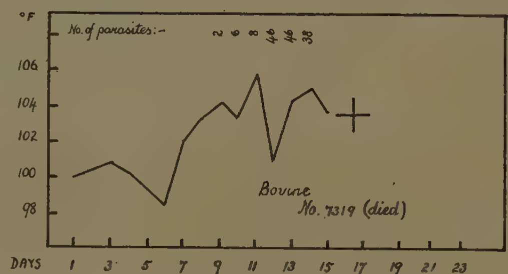


Bovine No. 5948: bitten once by three infected flies

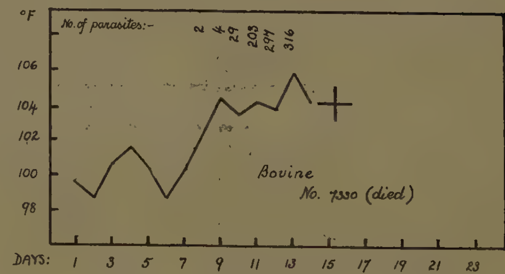
THE EFFECT OF ANTRYCIDE ON *T. VIVAX* IN TSETSE FLIES



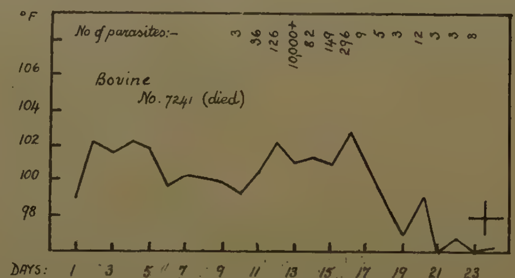
Reaction of Bovine No. 6991 to bites of 15 infected flies fed one day only



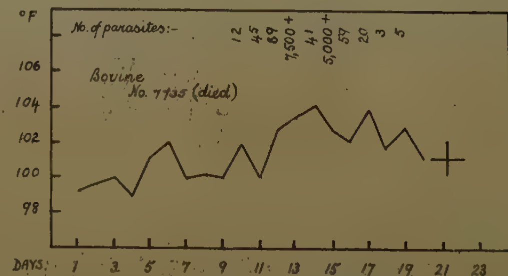
Bovine No. 7319: bitten once by one infected fly



Bovine No. 7330: bitten once by one infected fly.



Bovine No. 7241: bitten by three infected flies



Bovine No. 7735: bitten once by one infected fly.

had been fed on the Antrycide-treated beast, and the disease transmitted by the flies not previously fed on Antrycide-containing blood.

It is of interest, incidentally, that the treated ox No. 3608, was bitten 280 times by infected *G. pallidipes*; and that no trypanosomes were seen in blood or in gland smears taken regularly up to the eighty-fourth day after treatment. Further tests are now being made to determine whether or not trypanosomes in a latent phase are present in the system of this animal.

Discussion

In discussing the results of the investigation described above, it is appropriate to review briefly the cycle of development of *T. vivax* in the tsetse as described by Bruce and others (1910) and by Lloyd and Johnson (1924) together with the fly's mechanism of feeding.

The proboscis, or piercing and sucking organ, of a tsetse fly is a long lancet-like structure consisting of two tubes, one inside the other (*see* Fig. I). The inner, and narrower tube—called the hypopharynx—is a hardened extension of the salivary ducts. It is through this tube that the saliva passes outwards when the fly feeds. The outer, wider tube—called the labial tube—is for the passage of blood into the fly as it feeds.

When *T. vivax* occurs in the blood imbibed by the fly which is to become infected, the cycle of development of the parasite is restricted to the proboscis. The trypanosome settles down in this organ and undergoes a phase of multiplication which results in the formation of clusters or colonies (*see* sketch) of immature or crithidial trypanosomes. As development proceeds, individuals detach themselves and invade the hypopharynx where their development to mature, infective forms is completed.

When the fly has pierced its proboscis into an animal and has begun to draw-up blood, the infective trypanosomes in the hypopharynx are washed down by the saliva into the animal which, in due course, contracts trypanosomiasis. At the same time, blood is sucked up through the labial tube, sweeps through and bathes the clusters of developing *T. vivax* which have become established in the labial tube. It follows that as infected flies are feeding on an Antrycide-treated animal, the clusters of trypanosomes in the proboscis are immersed in a stream of blood containing the trypanocide.

The evidence set out in this article shows that Antrycide introduced into the blood stream of cattle will affect the course of infection of the bovine by *T. vivax*; its presence in the blood taken up, frequently and at short intervals, by infected *G. pallidipes* does not destroy the trypanosomes in the proboscis of the tsetse; nor does it affect, apparently, the development of the parasites once they have become established in the labial cavity. Infected tsetse-flies are, therefore, not rendered incapable of transmitting trypanosomiasis (caused by *T. vivax*) as a result of feeding on animals which have been treated with Antrycide. Furthermore, the virulence of the disease transmitted to cattle is unaffected.

Two other points, of minor importance at present, arise out of this investigation: The freshly infected flies used for transmission of *T. vivax* to the first few cattle provoked a chronic disease. Later on, the disease was usually more acute, and fatal. It seems as if the trypanosomes injected by the fly in the early stage of its infectivity, and occasionally at other times, give rise to a mild reaction to *T. vivax* in cattle. This is not always corroborated by observations in other investigations which are being conducted, but will be considered in studies of variations in the disease produced by the so-called virulent Emali strain of *T. vivax*.

It will also be noted that an infective tsetse fly may, sometitmes, fail to transmit *T. vivax* to a bovine on which it feeds. This failure cannot be attributed to the Antrycide. A similar case was met with among the untreated control flies. Usually, however, one infected fly will transmit a fatal reaction (*see* graphs).

It may not strictly be within the scope of this discussion to draw attention to other possible effects of trypanocides on the infectability of tsetses and on the trypanosomes transmitted to stock. The results given above are not complete in every respect. For example, the ingestion of Antrycide-containing blood either before or a day or two after a fly has obtained a good meal of infective, untreated blood may inhibit the initial stages of development of trypanosomes in the fly. This may take effect more readily in the case of the *congolense* and the *brucei* groups of trypanosomes which, unlike *T. vivax* and its closely related species, undergo the first phase of development in the stomach of tsetses, and may, therefore, remain longer in contact with the trypanocide.

Tests of the effect of Antrycide on *T. vivax* separated from the bovine blood or from the infected fly have not yet been carried out.

On the other hand, the trypanosomes in the fly may acquire a tolerance to periodic small doses of the drug; or they may become habituated to accumulated amounts so that when transmitted to untreated susceptible cattle they may resist the trypanocidal effects of the drug administered to those animals. In other words, this tolerance or drug-fastness may be acquired by trypanosomes in flies as well, perhaps, as in domestic animals.

These and other short investigations of practical importance are being continued in Kenya. The results so far obtained emphasize the necessity of fly control as well as the need of controlling trypanosomiasis by therapeutic treatment of stock and humans exposed to infection.

Summary

Brief reference is made to the control of trypanosomiasis by anti-tsetse measures, and by medicinal treatment of animals.

Trypanocidal compounds hitherto issued for animal trypanosomiasis have been useful chiefly as curatives or aids to recovery. Antrycide has some prophylactic properties also; it is stored in the subcutaneous tissue and gradually absorbed into the blood stream in sufficient quantity to destroy trypanosomes in the vertebrate host.

Its effect on *T. vivax* in the proboscis of *G. pallidipes* has been studied by feeding infected tsetses on a beast treated with Antrycide, and making observations on the disease subsequently transmitted by those flies.

The blood of Antrycide-treated cattle drawn up by tsetses at frequent intervals does not destroy *T. vivax* which has established itself in flies; nor does it affect development of the trypanosome to the mature, infective stage; not even after 18–19 meals over a period of 41 days, which is believed to be longer than the life of a tsetse in nature.

It is unlikely, therefore, that Antrycide in treated animals will sterilize infected tsetses. It may, however, so affect the trypanosomes in the fly as to give rise to a form of the disease in cattle which will not respond to further treatment by the drug.

In the circumstances, it is felt that measures for the control of tsetse flies must be continued.

TABLE I

Recording Age and Feeding of *G. pallidipes* Infected with *T. vivax* (Emali Strain)

Fly No.	Development of *T. vivax* (in days)	No. of full meals on treated ox 3608	No. of days saliva positive when fly first fed on clean ox	Longevity of fly (in days)
7	22	12	22	69
9	22	19	22	83
71	23	17	20	77
18	34	8	8	53
20	20	10	22	58
21	20	6	22	49
29	18	16	22	74
34	15	18	22	76
35	15	19	21	75
36	23	18	11	72
37	12	13	19	63
38	20	5	11	36
40	12	14	19	63
42	19	18	11	64
52	18	7	11	54
55	10	19	19	67
60	20	13	9	56
62	17	19	11	66
77	16	18	11	65
79	18	11	9	47

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Lloyd, Ll., and Johnson, W. B. (1924). The trypanosome infections of tsetse flies in Northern Nigeria and a new method of estimation. Bull. Ent. Res., Vol. xiv, Pt. 3, pp. 265–288.

REPORT ON DISCUSSION ON FERTILIZER EXPERIMENTS IN EAST AFRICA

Nairobi, 13th and 14th July, 1949

This meeting was called so that those directly concerned with fertilizer experiments in East Africa could discuss and compare the results, especially in their scientific and technical aspects.

The following papers were submitted:—

(1) "Fertilizer Studies on Uganda Soils" by H. L. Manning and G. ap Griffith, Department of Agriculture, Uganda.

(2) "Summary of Manurial Experiments in Zanzibar, 1933–1948" by A. K. Briant, Department of Agriculture, Zanzibar.

(3) "Fertilizer, Manure, and Cultivation Effects at Ukiriguru" by J. E. Peat, Empire Cotton Growing Corporation and Department of Agriculture, Tanganyika.

(4) "Soil Fertility Studies and Fertilizer Policy", and "Soil Fertility and Fertilizer Studies" (extracts from the 1948 report of the Scientific Department, Overseas Food Corporation, Kongwa) by A. H. Bunting and Mrs. I. Matheson, Overseas Food Corporation, Tanganyika.

(5) "Highland Fertilizer Scheme: Provisional Summary of 1948–1949 Results" by R. V. Holme and E. G. P. Sherwood, Highland Fertilizer Experiments Scheme, Kenya.

(6) "Report on Fertilizer Experiments, 1947–1948" by L. R. Doughty and D. W. Gourlay, E.A. Native Fertilizer Experiments Scheme, E.A.A.F.R.O.

(7) "Phosphate Trials in East Africa", by P. Robinson, E.A. Agriculture and Forestry Research Organization, Amani, Tanganyika.

(8) "Resultats des Essais de Fumere Minerale au Congo Belge" by A. Focan, I.N.E.A.C., Yangambi, Congo Belge.

(9) "Certain Work on the Availability of Phosphatic Fertilizers" and "The Effects of Different Methods of Placing Triple-supers and Soda Phosphate on Phosphate Uptake by Wheat" by G. H. Gethin Jones, Department of Agriculture, Kenya.

The Director, East African Agriculture and Forestry Research Organization (Dr. B. A. Keen, F.R.S.), was Chairman of the conference, and, in addition to those mentioned above, the following were present: H. H. Storey, F.R.S., and D. W. Duthie, East African Agriculture and Forestry Research Organization; H. C. Pereira and R. E. T. Hobbs, Department of Agriculture, Kenya; and H. B. Stent, East African Industrial Research Board.

Summary of Papers

In reviewing the field experiments which had been carried out by the Department of Agriculture, Uganda, during the past three years, Dr. G. Griffith said that the results had shown clearly the variability of response to phosphatic fertilizers, Uganda rock, soda-phosphate, and double superphosphate. These experiments had been successfully carried out in modern statistical design, but no conclusions could be drawn from the results and many factors such as time and method of application, would have to be studied for each type of phosphate before clear-cut results could be expected. The most encouraging response had been obtained with double super on sorghum, which gave a 32 per cent increase in yield. A highly significant height response had been obtained with Uganda rock phosphate on cotton in 1947, but this response was not reflected in yield. Although the difference between broadcasting and placing phosphate were not statistically significant, there was a fairly definite indication that broadcasting gave better results than placing.

Dr. Griffith also mentioned that the interaction between nitrogen and phosphate was not clear, and he pointed out that his work on nitrate accumulation in soil under fallow had demonstrated the presence of nitrogen equivalent to 400 lb. sulphate of ammonia or nitrate of soda, and these large amounts of naturally accumulated nitrate would obviously affect experiments with applied phosphate and nitrogen.

Summarizing the work in Zanzibar and Pemba, Mr. A. K. Briant said that nitrogen and organic manures had given definite positive responses on all the main soil types especially on the Kinongo soils. On the Changa soils in Zanzibar, soda-phosphate had produced very marked additional increases in the yield of maize (up to 60 per cent) and other

crops, and there were definite indications that phosphates were deficient on the Fue soils of Pemba. These are the two important clove growing soils in the Protectorate. Superphosphate has never in the past produced the striking responses on Changa soils that soda-phosphate has recently caused, but this may be due to the fact that superphosphate has almost always been applied as a top dressing. An experiment recently laid down on a Changa soil to compare the effect of soda-phosphate, superphosphate, triple phosphate and guano, all applied broadcast prior to the making of ridges for maize, indicate that superphosphate may be even more effective than soda-phosphate. On the shallow Kinongo soils overlying coral, microplots indicated that potash was deficient, but potash manures did not appear to be required on other soils. Lime applications had not produced positive responses except in two experiments in Pemba, one on rice and the other on sunflowers on a soil varying from a Kifusi to a Rendzina or similar type. On this soil potash caused a significant reduction in the number of heads produced by the sunflowers.

Mr. J. E. Peat described the results of experiments, mainly with cotton, at Ukiriguru and Lubaga in the Lake Province of Tanganyika. At Ukiriguru on the hill sand, organic manure had given the most striking increases in yield, and residual effects up to the fifth year after application were surprisingly large and quite definite. Tie-ridging had also given very significant and large increases in yield, and the marked effects of organic manure and tie-ridging had so far overshadowed the erratic responses to phosphate and nitrogen. There is some evidence, however, that superphosphate, now being tried for the first season, is giving a better response than did soda-phosphate.

The Overseas Food Corporation experiments at Kongwa and Urambo, in Tanganyika, were summarized by Dr. A. H. Bunting, who stressed the importance of having at least a rough breakdown of soils into types, in order to appreciate the difference in response from locality to locality. Another point to which he attached great importance was the carrying out of plant counts at harvest. It is possible that the erratic and inconclusive results which have been obtained in fertilizer experiments in East Africa may be due, in part at least, to the effects of treatment, or of purely fortuitous random effects on germination, and this factor should be taken into account in assessing the results of each trial. In the general exploratory experiments which he had carried out, mainly with groundnuts, nitrogen had shown little effect, even when placed, but phosphate had given definite increases, a higher response being obtained by placing the fertilizer compared with broadcasting. Applications of nitrogen had reduced the effect of phosphate, and there was considerable justification on the results of the first year experiments for eliminating nitrogen from the fertilizer prescription for groundnuts at Kongwa. Broad indications were obtained that the effectiveness of phosphate decreases with decreasing water or citric solubility.

Calcium nutrition is important in groundnut production, and a series of experiments with gypsum and with ground magnesian limestone had been carried out. The results showed that nearly all the Kongwa soils have sufficient calcium for the groundnut plant but on a grey soil at Urambo, in the Western Province of Tanganyika, there had been responses to ground limestone.

The Kenya Highlands Fertilizer Scheme was started with the main object of studying the relative efficiency of three types of phosphate: Uganda rock, locally manufactured soda-phosphate, and superphosphate, and Mr. R. V. Holme reviewed the results of the first year's field experiments, which had been carried out with wheat and maize. With Uganda rock, low dressings had given small increases, and high dressings seemed to reduce these increases. Soda-phosphate had given intermediate results, and superphosphate had proved to be the most effective of the phosphates. He had compared the response curves of superphosphate and soda phosphate by Yates' formula *$r = d\ (1 - 10^{-kx})$, in which r is the response to a dressing of amount x of fertilizer, d is the limiting responsie, i.e. the response to a very large dressing of fertilizer, and k is a positive constant which varies with different fertilizers. The results indicated that, weight for weight, triple superphosphate is nearly six times as effective as soda-phosphate, the actual figures being 45 lb. triple super equivalent to 257 lb. soda-phosphate. Mr. Holme suggested that there might be a component of Uganda rock which is detrimental to the action of the phosphate, and that this component is not removed in the calcining process in the production of soda-phosphate.

* *See* Crowther and Yates: "Fertilizer Policy in Wartime", *Empire Journ. Exp. Agric.*, Vol. 9, April, 1941.

As regards other fertilizers, there had been no definite response to sulphate of ammonia on the yields of wheat and little on maize, although nitrogen and superphosphate had shown a strong interaction in the early vegetative growth stage. Potash had shown preliminary results of great interest, particularly in improving the quality of wheat grain.

Mr. L. R. Doughty explained that the East African Native Fertilizer Scheme had not obtained conclusive results in the first year's field experiments, partly because of preliminary difficulties in organizing the work, but mainly because of unfavourable weather at planting time in several districts. Uganda rock had given very variable results, the overall effect being very small. Responses to super and soda-phosphate were not large, and did not reach the level required for significance, but there is sufficient evidence to indicate that, in the Nyanza Province of Kenya and the Eastern Province of Uganda, maize and sorghum will respond to phosphate treatment. In this series of experiments there were no marked differences in the responses to super and soda-phosphate. Nitrogen was effective in increasing the yields of maize and wimbi (Eleusine) but this effect was additive to that of phosphate with little or no interaction.

Describing the current year's experiments, many of which had not yet been harvested, Mr. Doughty said that, in general, superphosphate was giving a better response than soda-phosphate, and that there is some evidence of a marked response to Uganda rock with some crops after two or three applications on the same land. In the Lake Province of Tanganyika organic manure was giving a striking increase, in conformity with last year's results and with results obtained in experiments carried out by the Department of Agriculture there. This year, applications of nitrogen are also giving marked yield responses, equal to that of organic manure.

Mr. P. Robinson, Statistician in the East African Agriculture and Forestry Research Organization, summarized his findings on analysing the results of the Native and Highland Fertilizer Schemes, and pointed out the striking result of dividing experiments into groups in relation to annual rainfall:—wet (over 50") medium (40–50") and dry (under 40"). Regions of greater rainfall show higher responses to phosphate: this is probably accounted for by the fact that the soils of wetter regions are, on the average, more acid than those of drier areas, and are therefore more likely to be in need of phosphatic fertilizers. The conclusions from one year's experiments were bound to be tentative, but some useful indications could be obtained. Rock phosphate seemed to be too variable in effect to give much promise, but its cumulative effect requires testing. Response to soda-phosphate was less than that to super, the proportions being roughly 15 per cent to 25 per cent. The responses obtained with different dressings of phosphate were reduced to responses with a standard dressing, and, by means of a response curve, optimal dressings could be calculated, taking into account variable prices for both fertilizer and crop.

No conclusions could be drawn on the effects of nitrogen and calcium, and interactions between nitrogen and phosphate were not significant.

Monsieur A. Focan, from I.N.E.A.C., Yangambi, Belgian Congo, gave a short review of results obtained in fertilizer experiments over a number of years. In general, water appears to be the limiting factor in an equatorial climate of the Yangambi type, and maize responded to phosphate in the drier areas only in seasons of favourable rainfall. Cotton gave a clear-cut response to nitrogen in Southern Belgian Congo, but in the drier areas of the North the most striking responses were obtained with applications of cotton seed, nitrogen having only a small effect and phosphate being better than nitrogen but far less effective than the organic manure. Groundnuts did respond to lime, ashes and basic slag, but did not respond to nitrogen or Morocco phosphate.

With perennial plants there was little evidence of fertilizer response, since coffee, cinchona, and oil palms did not respond to minerals, and indications of response with sisal were not consistent. More recent experiments have emphasized the complexity of the problem of fertilizer response, particularly with oil palms. The young oil palm tree responds to minerals on an inert substrate, but variations in the composition of the mineral solution show marked differences, some mixtures having a beneficial effect while others are detrimental. Complementary studies of the modification of soil properties by mineral fertilizers have shown the importance of the relationship between the conditions of a fertilized soil and plant growth, and it is hoped that collaborative work by plant physiologists and soil scientists will yield results of value in planning field trials.

Mr. G. H. Gethin Jones gave the chief points in his pot culture work on the availability of phosphatic fertilizers, stressing at the start that he was not attempting to obtain a measure comparable with the response of crops to phosphates, but only to test the relative availability to plants of the different kinds of phosphate. At best, pot culture experiments can only give pointers to field experiments.

Citric solubility seemed to be a good measure of availability since it can be correlated with phosphate uptake in pot-culture work. This was brought out by the fact that the citric-soluble phosphate in triple super and in soda-phosphate appear to be equally available to plants at high concentrations. Uganda rock showed only one-fifth or one-sixth of the availability of triple super or soda-phosphate.

When the fertilizers were dressed on to the seed, the recovery from soda-phosphate was less than when a similar quantity was placed in the soil, whereas "water-soluble" triple supers dressed on the seed gave a relative higher recovery but germination was poorer.

Fineness of grinding was also tested with triple super, the number of particles of phosphate per cubic centimetre of soil ranging from 0.16 through 0.8, 8, 68, to over a million. In the first crop the intake was highest with fine grinding, but in later crops on the same soil the optimum moved towards the coarser particles.

The placing of phosphatic fertilizers in or between the rows causes local concentrations in the soil which might affect phosphate uptake, and a pot experiment was designed to test this point. Fertilizer/soil mixtures, with triple super and soda-phosphate, were used up to 1 per cent added P_2O_5, and with Uganda rock up to 10 per cent P_2O_5. There were no appreciable differences in height or in oven-dry weight of the seedlings under different treatments after 18 days growth, but slight symptoms of scorching appeared with the highest dressings. The uptake of phosphate from Uganda rock was not so high as from the two other forms, and the uptake from soda-phosphate was higher than from triple super, up to a P_2O_5 soil concentration of 0.5 per cent. Above this the intake from soda-phosphate decreased, while that from triple super rose steadily, a possible explanation being that the free sodium carbonate in soda-phosphate had affected phosphate uptake at the higher concentrations probably by raising the pH of the soil.

These latter results led to an experiment in which wheat was grown in box compartments 40 × 8 inches in area and 5 inches deep. Equal dressings, in terms of total P_2O_5, were applied as soda-phosphate and triple super, at the rate of 118 lb. P_2O_5 per acre. The phosphates were mixed with a mass of soil and applied in the row, between each two rows, and between alternate rows. Samples of seedlings were taken after 19 and 40 days' growth, and further samples will be taken, as thinnings, as the plants increase in size. The results obtained from the first two sets of samples are not conclusive, but they do suggest that the optimum placement of soda-phosphate should be nearer the plant than with triple super.

Discussion

The Chairman suggested that instead of discussing each paper in turn, it would be better to consider four main problems, common to most of the papers:—

(a) *Response to phosphatic fertilizers*: e.g. the value of soda-phosphate compared with other forms of phosphate.

(b) *Response to other fertilizers and manures*: e.g. nitrogen, potash, lime and organic manures.

(c) *Factors affecting fertilizer response*: e.g. germination, grass rotation, nitrate accumulation in soil, the limiting effects of nitrogen levels on the response to phosphate and vice versa and the effects of low, medium, and high rainfall on fertilizer response.

(d) *Indicator experiments and plant and soil analysis*: e.g. microplot experiments, pot cultures, methods of soil analysis, and fractionation of soil phosphate.

It was not intended that this should be treated as an agenda and it was unavoidable, and in fact desirable, that there should be considerable overlapping in the discussion.

Several general points were considered first. It is highly desirable that the soils on which fertilizer experiments are being laid down should be clasified or typified as far as is possible. This does not mean that a detailed soil survey is necessary, and in most cases a rough subdivision will be all that is possible. But this may be enough to explain variations in response which would otherwise prevent conclusions being drawn. The most rapid method of working out a preliminary soil map is to travel extensively in the area to see the broad differences, then make a few traverses to de-

marcate the boundaries, and finally take as many soil samples as can be analysed. The main points to look for are colour, the profile sequence, topography (e.g. catena), correlation with geology, and changes in vegetation.

Dr. Griffith suggested that more attention should be paid to the possibility of washing of fertilizers from one plot to another, as he suspected that many experiments gave inconclusive results because fertilizers had moved from treated to control plots. On sloping ground this movement might be by subsurface seepage of soil water, which would be difficult to guard against, and the yield of control plots should be watched carefully in case they are markedly higher than is usual for the area. Every effort should be made to protect plots from the effects of neighbouring plots; sometimes this would mean a major alteration in the lay-out of the experiment.

Another point of general interest is the possibility that early rains followed by a relatively dry experimental period may disturb the balance of the experiment, in that the stimulation of growth by fertilizers may cause extensive shallow rooting, so that these plants are more liable to suffer from drought if the seasonal rainfall is erratic. It is common to find that early in an experiment the treated plots show more vigorous vegetative growth than the controls, but this is often not reflected in the final yield. In areas liable to drought it would be better to bury the fertilizers in order to stimulate deep rooting.

The natural hazards of germination, apart from the detrimental effects sometimes found by placing fertilizers near the seed, should also be taken into account. In small plots the failure of a few seeds to germinate might seriously affect the results. In the Groundnut Scheme trials, plant counts are taken at harvest, in order to take this factor into account, and in the Highlands Fertilizer Scheme the plants are thinned down to a common level three to four weeks after planting.

Response to phosphate.

As regards unprocessed Uganda rock phosphate, small responses have been obtained by the Uganda Department of Agriculture over a wide range of conditions. On the other hand, in the 1947–48 experiments of the Native and Highland Fertilizer Schemes, rock phosphate produced only a slight effect on some soils, and on the average its effects were small and inconsistent. In these latter experiments, large dressings (nine cwt. per acre) of rock phosphate gave smaller increases in yield than half that dressing. It was suggested that soil acidity might be the key factor in this, and there are indications that soils of pH 5 or less show more definite responses. The cumulative effect of Uganda rock requires study, as there is some preliminary evidence that repeated dressings on an acid soil give visible responses.

Comparisons between superphosphate and sodaphosphate had not been conclusive, and it seems likely that soil factors, particularly pH, are involved. It is possible that sodaphosphate is more active in an acid soil, and it is also possible that sodaphosphate contains trace elements, such as fluorine and boron, which may have detrimental or beneficial effects on plant growth. The effects of these phosphatic fertilizers on germination was also discussed, and the point was brought out that plots receiving both sodaphosphate and sulphate of ammonia may show reduced germination, because of the toxic effect of free ammonia liberated from sulphate of ammonia by the alkaline sodaphosphate.

As regards the manufacture of sodaphosphate, Mr. H. B. Stent, Acting Chairman of the East African Industrial Research Board, pointed out that none of the fluorine in Uganda rock is removed in the process but some of it is changed to sodium fluoride. The free sodium carbonate in the final product, which may possibly affect crop response, could be neutralized by adding gypsum, or by mixing triple superphosphate with the sodaphosphate. It cannot be leached out with water.

Other points brought up in the discussion were the use of superphosphate as a standard in field trials, giving comparisons on a superphosphate response scale; the possibility that phosphate stimulates microbiological activity in the soil; the need for further work on reinforcing organic manures with phosphates, and the suggestion that we may find that some plants have a greater power of uptake of soil phosphate, and if so, these plants might be used in crop rotations.

Organic Manures.

The most striking effect of organic manures had been reported from the Lake Province of Tanganyika, where a dressing of five to seven tons of cattle manure on cotton and sorghum had given increases up to 50 per cent in the first year, and residual effects of considerable value had been found up to four years after application. The soil is not an exhausted sand,

since control plots are giving 500–600 lb. seed-cotton year after year.

It was clear that the effects of organic manures must be split up into the effects of the mineral content and the other effects such as that of soil moisture. The nitrogen, phosphate, lime and potash in organic manures are probably present in organic combination, and their effects on plant growth may be different from the inorganic forms. Yet, although this might explain the first year's results, it does not seem to account for the marked residual effect over a number of years. One important point is that there is no visible sign of organic manure lasting in the soils as it disappears with the rapidity usual for tropical soils.

These Lake Province experiments were carried out at an altitude of approximately 4,000 feet, but Mr. R. E. T. Hobbs of the Kenya Department of Agriculture stated that at higher altitudes, 7,000 to 8,000 feet, wheat straw remains in the ground for two or three years without rotting completely. He had found residual effects from four tons of farmyard manure at these higher altitudes. Reference was made to publications by Dr. J. E. A. den Doop, who had suggested that even small dressings of organic manure might act as a "trigger" in stimulating microbiological activity.

From the discussion it was clear that there is great need for basic research on organic manures, since the results of field experiments cannot be explained from existing knowledge.

Other Fertilizers.

The effects of nitrogen dressings in East Africa have been so variable that conclusions cannot be drawn yet, and the evidence is so conflicting that much further experimental work will be necessary to clarify the effects. Until recently nitrogenous fertilizers have been rather neglected in field trials, since crop economics made it too expensive for extensive use, but so far as the evidence goes, the main problem is to find the right time to apply nitrogen. Although early applications have given responses in some trials, there has sometimes been a stimulation of vegetative growth which was not followed by an increased yield of grain. It is possible that later applications, just before the start of reproductive growth, might give more definite responses, and this is well worth further investigation. Interactions between nitrogen and phosphate have been found, but here again the time of application of nitrogen may be the key factor.

As regards potash, there has been little or no prior evidence of definite potash deficiency in the areas which have been used for fertilizer trials. Yet, dressings of potash have improved both the quality and quantity of grain in the Kenya wheat trials, and applications of this fertilizer appear to be economically important. Elephant grass seems to take up large quantities of potash, and in Uganda it was found that as much as 1,200 lb. K_2O per acre may be taken up in the resting period under elephant grass.

Deficiencies of minor or trace elements may possibly play a part in fertilizer response, but the only available evidence of the action of these is that a stock disease called "Nakuruitis" has been attributed to cobalt deficiency, and excess of cobalt has been given as the cause of a disease of sisal. A chemically rich soil which gives poor crop yields may be suspected of minor element deficiency, and in such cases the Kenya Department of Agriculture recommends heavy dressings of cattle manure. However, unless further evidence of minor element deficiencies is found, the first task is to test the effects of adding major elements, such as N.P.K. and Ca, on the assumption that minor elements are not a limiting factor in crop production.

Factors affecting fertilizer response.

The effect of soil moisture in fertilizer experiments is clearly of the utmost importance, and methods of treatment which will conserve soil moisture may even be of greater value than the application of fertilizers. It was suggested that dressings of farmyard manure may conserve some of the moisture in the soil, but experience to date has indicated that mulching is more effective than digging in organic manure. It seemed unlikely that the relatively small quantity of organic matter added to the soil in a normal dressing of farmyard manure would be sufficient to have much effect on the moisture-retaining capacity of the soil. Mulching is far more effective per ton of material than organic manure which has been dug into the soil.

Dr. H. C. Pereira, Kenya Department of Agriculture, gave a short account of field trials in which comparison had been made between organic matter dug into the soil and used as a mulch. The evidence suggests that with coffee it is better to use grass as a mulch rather than to dig in farmyard manure or compost. The conservation of soil moisture under grass mulch had been measured, and it had been found effective to a depth of at least three feet, whereas

unmulched plots had dried out to the wilting point. In this work on mulching of coffee, every experiment with grass mulch had given positive results, and the evidence was clear-cut in favour of mulching. It seems, therefore, that, with perennial crops at least, the conservation of moisture in the top soil is much more important than incorporation of organic matter into the soil.

In discussing organic manures, it was pointed out that the terms "farmyard manure" and "compost" are used to cover everything with some organic matter in it. In preparing these it would be better to separate the coarse material, which would be valuable as mulch, and to prepare the finer material for digging into the soil.

The question was raised as to whether it would be feasible to mulch annual crops, and it was agreed that, although there is evidence that trash farming can be successful in Kenya, our knowledge of trash or stubble farming is not sufficient to permit definite conclusions, and further investigation would be of great practical importance.

Soil Nitrate.—Dr. Griffith described field experiments in Uganda, on two major soil types, in which large accumulations of nitrate had been found, following broadly the two distinct rainy seasons. He suggested that variations in the accumulation of nitrate might account for the uncertain responses in Uganda fertilizer trials, particularly with nitrogen, since responses were low when soil nitrate was high, and vice versa. Leaching of nitrate into the subsoil had been found, and in one soil the zone of accumulation was seven to eight feet below the surface, representing the "tide-mark" of percolating rain. It was pointed out that phosphate accumulation also occurred in this zone, and the possibility was suggested that these two acidic radicles might carry bases down with them.

In this work on nitrate accumulation, soils under bare fallow had shown the highest amounts of nitrate, and the possibility of practical exploitation of this was discussed, one suggestion being that very wide spacing of plants might allow nitrate accumulation on the relatively large bare patches. Mr. Briant mentioned that in some parts of Zanzibar cowpeas are planted one yard apart, and natives are very reluctant to adopt closer planting: this might have some bearing on nitrate accumulation in bare soil. This and other native agricultural practices might assist in explaining some of the peculiar facts which were emerging from investigational work, and the advisability of learning more about native agricultural folklore was noted.

Effects of Weeds.—The effects of weeds was also discussed, and several inexplicable characteristics were brought to notice. For instance, results from a wide range of soils, crops and climates show that weeds are most detrimental while the crop is young, and if they are not kept down at that stage no amount of subsequent cultivation will undo the damage. Even a light weed infestation has this effect. Conversely, after clean weeding the young crop you can let weeds grow without affecting the yield. This is contrary to what one would expect in theory, since there should be plenty of soil moisture and nutrients for both crop and weeds in the younger stages. In this connexion mention was also made of the observations of Spencer Pickering in the early years of this century, who found that the effect of growing grass round apple trees is to arrest all healthy growth and to stunt the tree. This effect was also produced when perforated trays of sand containing growing grass were placed on the surface of the soil in which trees were growing, so that the washings from the grass went straight down to the tree roots. No satisfactory explanation has yet been found for this, and it must be assumed that toxic substances were produced by the grass roots.

Indicator Experiments and Plant and Soil Analysis

Microplot Experiments.—Mr. Holme, who devised the microplot technique, opened a discussion on this subject by pointing out that microplot experiments should not be looked upon as a quick substitute for field experiments. The function of the microplot trial is to study those factors which are normally assumed or guessed at in full-scale field experiments, such as depth of application of fertilizer or time of application. Comprehensive N.P.K. field trials with, in addition, different depths and times of application would be most cumbersome, but the answers can be obtained quickly and cheaply by the microplot technique. As exploratory trials the microplots are particularly useful, in that a large number of factors can be tested in a short time in order to find which are likely to be worthy of trial in field experiments. Small differences in the yield figures are of little importance, as only large increases, from about 50 per cent upwards, give any real indication of treatments likely to be effective in field trials. Statistical calculation is therefore usually unnecessary, so long as the experiments have been properly designed.

Thus microplot trials play a part, but only a part, in the study of the potential fertility of a soil. The order of study might be as follows:—

(*a*) Soil analyses to obtain a general view of the natural fertility of the soil and to find major deficiencies.

(*b*) Pot cultures to test the availability of a range of different fertilizers under standardized but artificial conditions.

(*c*) Microplot trials to sort out field methods of applying the fertilizers and to compare a variety of soils under field conditions.

(*d*) Full-scale field trials to find the effects of treatments on the final yield of crops.

Pot-cultures.—The mention of pot-cultures in this suggested outline of procedure in studying soil fertility started a short discussion on pot-culture work, in which the importance of even distribution of roots in the pot was emphasized. With the ordinary porous flowerpot there is a tendency for roots to concentrate on the sides of the pot, leaving the centre of the soil-fertilizer mass with less than its true share of roots. By sealing the sides of these porous pots with wax or some other inert material, good root distribution can be obtained.

Good aeration in the pot is also important, and the method employed by Mr. Gethin Jones is to wet the soil thoroughly, pass it through a coarse sieve, and thus obtain a puffed structure with good aeration and sufficient moisture. With Kenya soils he had not found it necessary or advisable to dilute the soil with an inert substance such as sand or crushed flint.

Soil Analysis.—Uniformity in soil analytical methods should be obtained when the Analytical Committee, which was set up in 1948, can function actively with a full-time analyst to test the existing methods and to keep up-to-date with progress in analytical technique. It is hoped that this will be possible in the near future.

The methods of estimation of "available" phosphate are now receiving much attention, since field trials are difficult to correlate with those methods which use weak acid as the extracting agent, e.g. Dyer's citric solubility method and Truog's extraction with dilute sulphuric acid. Dr. H. F. Birch, of the East African Agriculture and Forest Research Organization, has begun an investigation of extraction methods recently developed in America, and he has found that acid-soluble plus adsorbed phosphate, extracted with a weak solution of ammonium fluoride in hydrochloric acid (pH 1.7) and adsorbed phosphate, extracted with neutral ammonium fluoride solution, give better correlations with field trials than the older methods do. A third extracting agent, containing ammonium fluoride and hydrochloric acid at pH 3.8 gives values which can be used to explain the degree to which the phosphate ion is bound within the clay complex. While this method is not entirely satisfactory, it has the advantage that the phosphate ion is treated as part of a physico-chemical complex, while the older methods merely extracted one fraction of the phosphate and assumed that it was available to plants.

NOMENCLATURE AND CLASSIFICATION OF HIDES AND SKINS

By M. H. French, Adviser, E.A. Hides, Tanning and Allied Industries Bureau

(*Received for publication on 5th August*, 1949)

What is the difference between a hide and skin and when does a skin become a hide? These questions are almost invariably asked by a newcomer to the hides and skins industry and yet the answers are not readily obtainable from a standard dictionary. Fowler's Concise Oxford Dictionary, for instance, gives the following meanings of "skin": (*a*) flexible continuous covering of human or other animal body; (*b*) hide of flayed animal, with or without the hair. The same authority explains "hide" as animal *skin*. When it is found necessary, in such a dictionary, to explain the meanings of each of the words "hide" and "skin" by a statement which includes the other word, it is understandable that newcomers to the hides and skins trade are somewhat puzzled by the nomenclature.

Reference to the definitions of "hide" and "skin" in the Hides and Skins Trade Ordinance of the three East African territories reveals certain small differences in definition but generally a "hide" means the integument covering, or removed from, a bovine animal whilst "skin" is reserved for the same tissues from sheep, goats and sometimes from game animals. Textbooks on physiology or histology usually omit a definition but proceed directly to a description of the various tissues which, in aggregate, are called "skin". Microscopic examinations of hides and skins show that they are all built from the same types of tissues although the proportions and sizes of the different components vary between species. In fact, the two terms are essentially the same histologically but, for convenience, the trade in domestic and game hides and skins has been forced to adopt certain arbitrary interpretations and there is ample excuse for the novice inquiring when does a "calf skin" become a "hide" or why a zebra should have a "skin" when a horse has a "hide"?

Size, substance and end-usage are factors which influenced the trade distinctions. Light, thin coverings such as those from sheep, goats and game animals are usually called skins (but the term "hide" can be applied to thick or heavy game integuments, e.g. buffalo). Camels and horses have hides whilst reptiles, birds and fishes have skins. In the bovine family the trade differentiates between calf skins and cattle (steer, cow or bull) hides and, in East Africa, the dividing line is at 4 lb. air dry weight.

Having divided the trade into "hides" and "skins" there are many further descriptive terms used in the separation and marketing of these products. These will be treated briefly later in this article but it is first necessary to refer to an important East African distinction used for classifying both hides and skins.

Some 40 years ago, as the result of the efforts of certain interested parties, small lots of hides and skins were prepared by suspension in open-sided sheds instead of by the traditional native method of pegging on the ground. At first a certain amount of opposition to this shed drying was encountered but by the end of the 1920's the numbers had increased to an extent which allowed overseas tanners to appreciate and pay for the great superiority in tanning value of hides and skins prepared in this way. In 1932, an experiment was carried out jointly by the Consultative Committee on Hides and Skins of the Imperial Institute, London, and the Kenya Veterinary Department. It was designed to test the superiority of hides dried by suspension in sheds, and the experiment fully confirmed the experience of tanners that hides dried by suspension in sheds and which were referred to in the trade as "shade-drieds" were greatly superior in tanning value to the ordinary run of "sun-drieds", i.e. hides dried by pegging on the ground, flesh side uppermost.

It has been the custom, for many years, for the trade to pay a premium for "shade-dried" hides and skins and the term "shade-dried" was introduced when it was thought that the essential factor responsible for the increased tanning value was shade. In recent years, however, it has been clearly demonstrated that shade, as such, is not the important factor and that the basic principle involved is "suspension", either in a frame or over ropes or wires but not over poles.

Experience has also shown that hides dried by suspension in frames in the open, so that the planes of the hides run in an east and west direction, are fully the equal of hides dried in a similar manner in sheds. Recent experiments in Nairobi have confirmed that skins dried on ropes or in frames in the open are also indistinguishable, in the finished leather

stage, from skins dried by suspension over ropes or in frames in the shade. In fact, before and during the war years, many hides were sold as "shade-drieds" which had been dried not in the shade but in frames in the open. The past terminology therefore does not now correctly describe the products nor does it emphasize, to producers and consumers alike, the important distinction betweeen the two classes, i.e., one having been dried after suspension and the other after pegging on the ground.

Since a hide pegged on the ground in the shade is not of the same tanning value as one which has been suspended in the shade or in the sun, and because it is important to emphasize, in the nomenclature, the essential factor responsible for the enhanced value of suspension-dried articles, it has been decided to change the existing terms of "shade-dried" and "sun-dried" to "suspension-dried" and "ground-dried". The necessary legislation to make these terms compulsory will be introduced, it is hoped, in all three territories in the near future and in the meantime overseas consumers, East African shippers and dealers in hides and skins are being asked to introduce this change as soon as possible.

In the above discussion only hides and skins, which have been cured by air-drying, have been considered. There is another method of preparation, namely "salting", which will become more important in the larger abattoirs and slaughter-houses of East Africa in coming years. In salting hides and skins they are first soaked in strong brine solution and later laid away in piles with an adequate amount of salt sprinkled on the flesh side. After salting in piles in this way for some three weeks, the hides and skins can either be shipped in the "wet-salted" condition or may be dried by suspension and sold in the "dry-salted" state.

Hides and skins are therefore referred to first by their family name and then classified according to the method of curing, i.e. "suspension-dried", "ground-dried" or "salted". Each of these classes is then further divided, in East Africa, according to species differences, e.g. "humped" and "humpless" hides and "woolled" and "hair" sheep skins, before being further broken down into weight ranges or qualified by the name of the district of origin or port of shipment, the method of preparation or the seasons of production.

There are many terms used for describing hides and skins and, in this article, no attempt has been made to make the list exhaustive. All that has been attempted is to describe the meanings attached to some of the more commonly used terms in so far as they apply to East African conditions. "Humped" hides, as their name implies, are derived from cattle of Zebu origin or crosses of this type with other breeds to give offspring possessing a marked thoracic hump. "Humpless" hides is the term given to hides from non-humped animals, i.e. from European breeds, from European/Zebu crosses which possess no or only small cervico-thoracic humps, or from Ankole (Sanga) cattle.

Having separated hides and skins into families, species and classified them according to method of preparation, each class is broken further into weight ranges and the usual East African procedure is to call dried hides of 0–4 lb. "calf skins", hides of 4–8 lb. weight "lights", hides of 8–12 lb. dried weight "mediums", the 12–16 lb. weight range "heavies" and hides of over 16 lb. dried weight "extra heavies". Occasionally one also hears the word "kip" applied to hides and a kip is a dried hide of between 4–10 lb. dried weight, whilst hides of between 10 and 12 lb. dried weight are referred to as "over-weight kips". Hides over 12 lb. in dried weight are usually referred to as "hides". Another past distinction made by the trade in hides is to refer to them by the port of shipment, i.e. "Mombasas" and occasionally they have been referred to by the district of origin, e.g. "Kampalas". A more recent break-down of each class has been made on the basis of the method of flaying and to-day there are "knife-flayed" and "hammer-flayed" hides and a premium is paid for the latter because hides which have been "biffed" off with a hammer will probably have suffered less damage from knife cuts and gouge marks than those which have been flayed entirely by knives.

In some parts of the world, hides are further broken down into "packer", "butcher" and "country" hides. A "packer" hide, as the name implies (or "frigorificos", as they are sometimes called) comes from the large meat processing plants. "Butcher" hides is the term usually reserved for the products of the large urban abattoirs, although in East Africa the term is also used to describe the products from the small up-country butcheries. "Country" hides is the term usually given to the products of small urban and village butcheries in other parts of the world and is a term which should more strictly embrace the product of the small up-country butcheries in East Africa. The term "native" hide is an

American expression to indicate a hide which is free from brand marks but, in East Africa, the term is usually understood to mean the article produced from African-owned stock. The expression "branded" hide needs no explanation. The term "butcher" hides and skins is also used in East Africa to draw a distinction between hides and skins removed from slaughtered animals and those from animals which have died from natural causes. Hides and skins from animals which have died from old age, disease, starvation, etc., are usually referred to as "fallen" hides and it would be a great advantage to the industry if all such fallen hides and skins could be separated from and not mixed in with hides and skins from slaughtered animals. The reason for this is that, when an animal dies from natural causes, it is often some time before the hide or skin is flayed from the carcass and in any case blood has not been drained from the surface blood vessels and consequently the risk of putrefaction is greater than if the animals had been slaughtered.

A further separation of hides is sometimes undertaken into the following:—

"Steer" hides, which means hides from animals castrated early in life. "Cow" hides is the term usually reserved for hides from animals which have had one or more calves. "Heifer" hides, which are from females which have not had calves, are often included with "steers". "Bull" hides are often separated because of their uneven substance and heavy coarse texture. "Stag" hides are from animals castrated late in life and resemble "bull" hides more closely than they do "steer" hides. "Slink" hides (or skins) are obtained from unborn calves.

In most parts of the world the trade divides hides and skins into "Winter" and "Summer" products or into "wet" and "dry" season articles but, in East Africa, this has not yet been attempted. The reason why lower prices are paid for "Winter" hides is that they usually carry a thicker coat of hair and therefore the leather yields are lower. In the tropics and sub-tropics, the climatic differences between wet and dry seasons are not such as to favour the growth of longer hair and, in East Africa, some areas may be experiencing wet season conditions whilst others are in the middle of their dry season and it has not been found easy to separate the East African trade into "wet" and "dry" season articles.

Hides from humped, Zebu cattle and from the indigenous Ankole herds are thin and light in weight in comparison with their surface area and are usually referred to as "spready". Hides from European breeds have a thicker substance and a greater weight per unit of area and are consequently described as "plump".

East African goat skins are of a haired type and usually are separated into districts of origin or ports of shipment. In addition, however, a distinction is now being introduced to differentiate those goat skins which have been "pulled" from carcasses from those which have been flayed with a knife. Many of the "pulled" skins, which are taken off in much the same way as when skinning a rabbit, are dried flesh-side outwards and without the skins being cut and opened out. In this condition they are usually referred to in the trade as "cased" skins.

Sheep skins, as already stated, are usually divided into "haired" and "woolled" types and are sometimes further divided by a prefix indicating the district of origin or port of shipment. In the "woolled" class, further distinctions are often made to indicate wool length (i.e. "half wool", "three-quarters wool", etc.). Both goat and sheep skins are qualified by specifying their weight per 100 skins or per one dozen skins.

Having differentiated hides and skins into classes, weight ranges, origins, etc., the trade almost invariably further subdivides each group into Grades I, II, III (and sometimes IV), and rejects. Grading is such a specialized operation, however, that it is outside the scope of this article.

There are two further terms which are slowly creeping into the East African trade in hides and skins. These are "half-tanned" hides and skins or "half-tanned" leather and are applied to hides and skins which have been partially processed and partially converted into leather. According to the definition of leather, these articles qualify for inclusion as leather but, because of past trade custom, the term "half-tanned" hide or skin is still retained. The term "crust" leather could also be used to describe these semi-processed articles but "half-tanned" hide has also a slightly more specific meaning in that it refers to a type of vegetable-tanned hide which has been produced in India for many years and marketed as "East Indian kips".

Sheep and goat skins are beginning to be partially processed in East Africa and sold overseas in the "pickled" form. "Pickled" skins are the "pelts", after passing through the various beam-house operations but before undergoing any tanning processes.

SOIL AND WATER CONSERVATION IN THE PUNJAB

By Colin Maher, Senior Soil Conservation Officer, Department of Agriculture, Kenya

If erosion continues its disastrous course in the Punjab it will not be because causes and remedies have not been laid well and truly before official eyes in the Province. Following the volume on "Erosion in the Punjab—Its Causes and Cure" by Sir Harold Glover, published in 1944 and which was reviewed in this Journal in April, 1947, comes an even longer volume of 290 pages, in cloth boards, with 30 photographic plates and 41 figures entitled "Soil and Water Conservation in the Punjab" by Dr. R. Maclagan Gorrie. This report or manual was published in 1946 (the name of the publisher is not given) and sold for Rs. 5 or Sh. 7/6d. The previous work which is mentioned above cost Sh. 23 for a mere 143 pages.

This manual "attempts to lay down the details of protective field work in the various phases of afforestation of catchments, reclamation of torrent beds and wasteland and the control of run-off from cultivation". Sir Evan M. Jenkins, Governor of the Punjab, in a foreword recommends this manual as a means of passing knowledge of preventive and remedial measures against soil erosion to officers of all departments concerned with rural affairs.

This book was received for review in July, 1948, nearly two years after its publication, as was the case with the previous book. The author, Dr. R. Maclagan Gorrie, D.Sc., F.R.S.E., of the Indian Forest Service, has been closely concerned with soil conservation questions for many years. Many readers of this journal will remember his pamphlet entitled "The Use and Misuse of Land" in which he included a description of soil conservation matters which he was able to study during a visit which he made to the U.S.A. in 1934. It is to be expected therefore that an officer with this background would produce a work which would contain a great deal of interest to agricultural and soil conservation workers in East Africa. While it is not possible to do justice to such a considerable compendium of information and advice on soil conservation matters within the space which can be spared in this journal, this considerable work justifies a review which is more than a passing notice of the publication.

The first two chapters of the manual consist of a *rèchauffée* of information concerning the dynamics of erosion and the relation of erosion to physical properties of soils and so forth.

The author goes on in Chapter Three to discuss various types of contour furrows, narrow base terraces and other devices for increasing the absorption of rainfall and preventing run-off. He rejects the broad base contour banks or terraces such as are commonly employed in the U.S.A. and other parts of the world, including the European areas of Kenya Colony, as presenting too hard a job for Indian bullock power. He also fears that too much sub-soil would be exposed on the shallow soils and that the banks would take too much room unless cultivated throughout. He observes that the Punjabi cultivator prefers square fields and goes to a great deal of additional labour in constructing narrow base terraces or *wattbandi*, declining to accept the necessity of following contours—although rice fields are always protected by contour banks of puddled clay. In the Punjab, as in East Africa, difficulty is experienced in contouring land due to the existence of old field boundaries. Dr. Maclagan Gorrie refers to the preferable custom in the Bombay Presidency of carrying out contouring first before consolidation of holdings has been introduced. The old field boundaries remain until the holdings have been registered and at consolidation the contour ridges automatically become the new field boundaries. In the Punjab contouring had been delayed in the hope that at the time of consolidation of holdings land would be contoured.

The following extract will strike a familiar note to many an agricultural officer in the reserves of East Africa:—

> "3. 12. The idea is commonly held by many civil officials that one '*wattbandi week*' each year in a district is effective. It may salve the civilian conscience, but the fact remains that proper field technique is not gained through a burst of feverish energy once a year, but is based upon a *habit of mind*. Run-off control only starts with the making of a *watt;* the rest of the cultivator's life must be a study of how this start in run-off control can be improved upon. Maintenance must be preached until it is done as a matter of course. We are far removed from this standard."

The writer gives a table which only allows of wattbandi or narrow base terraces and contour

ridging up to slopes of eight per cent and advises bench terracing above this. This compares with practice in Kenya Colony where narrow or broad base terracing is considered satisfactory up to 12 per cent and for certain purposes narrow base terraces are found adequate up to 20 per cent, whereas bench terracing is considered practicable up to 30 per cent. Dr. Maclagan Gorrie advises that nothing over 20 per cent should be terraced in the Punjab except by clearing contours by the use of mattocks for sowing grass or planting trees or by making short lengths of "interrupted but carefully contoured trenches" for afforestation.

Throughout the report one is struck by the high cost of work for protection and reclamation of land in the Punjab. For example, in terracing and trenching by hand:—"Ploughing any average acre of sloping land with a "raja" plough may be taken at Rs. 12. Digging 10 x 1 x 1 trenches at 15 ft. horizontal interval and with a berm continuous along each contour row costs Rs. 16 on the basis of 1¼ annas per trench. The pre-war provision of Rs. 8 per acre for 10 ft. trenches allowed only 100 trenches per acre, and these were scattered irregularly and not linked up in continuous contour lines. Any combination of spaced furrows cut either by plough or by hand should cost less than this".

(*Note*: The value of the rupee may be taken as Sh. 1/50).

Again the cost of *wattbandi* and contour ridging using bullock-drawn *karahs* or small scoops "varies from Rs. 40 per acre to Rs. 550 per acre according to the slope and hardness of the deeper layers which have to be ploughed or broken before they can be shifted with the *karah*. These costs are for slopes of four per cent to 10 per cent but are higher than they need be owing to the Punjabi's fetish for making square fields".

In view of the correspondence in the East African press from time to time in which African labourers are compared unfavourably with Indian coolies it is interesting to note that Dr. Maclagan Gorrie states that the coolie can excavate 85 cubic feet of earth a day. This compares with task work of 100 cubic feet per day, up to 150 cubic feet and 200 cubic feet in easy soil, which is done by labourers in Soil Conservation Service labour gangs in Kenya Colony.

The cost of terracing with mechanical equipment in the Punjab will be commented upon later as it occurs later in the report under review. It may be observed here, however, that it would be difficult to advocate in East Africa the expensive practice of building brick spillways from fields to remove surplus water which is being ponded behind *watts*, even though it is stated that such spillways built of brick and cement cost only about Rs. 25 each.

The maintenance of terraces is a perpetual bugbear to the agricultural officer and soil conservation officer in East Africa. Irresponsibility, poverty and ignorance are associated characteristics; equally there is—". . . the common Punjab experience of neglected maintenance. In many Punjab districts *watts* were built by returning soldiers nearly 30 years ago but have since been neglected and remain as isolated humps in eroded fields. Similarly one finds brick spillways standing as isolated and useless tombstones in the alignment of a *watt* or *bund* which has not been maintained at the correct height, and a cattle-track or footpath has eventually dug so deep as to let all the water through there instead of over the sill".

The author goes on to give instructions on the lining out of contours and the construction of terrace banks. The use of a striding level for contouring with the use of a mason's level on a wooden frame may be cheap, but it is tedious; and with the cost of terracing as high as the figures given it would appear well worth while to adopt a more rapid and accurate instrument such as a dumpy level or Watts' quickset level especially since these levels are required for reasonably rapid setting out and checking of diversion ditches and other similar structures.

Throughout the report the author draws freely upon American technique and adopts or copies diagrams from American pamphlets and textbooks on soil conservation. On Page 48, Fig. 11 appears to be a copy of Fig. 28 of Farmers' Bulletin No. 1789 of the United States Department of Agriculture, "Terracing for Soil and Water Conservation". It is somewhat misleading, however, to give this diagram as being of a terrace made by a 7 ft. blade pulled by a D2 Caterpillar tractor. The original diagram in the American pamphlet is for a terrace bank made by a 10 ft. blade terracer such as is normally pulled by a D6 Caterpillar diesel tractor. The reviewer, after fifteen years' experience of terracing, would doubt very much that it is possible to build a terrace of the dimensions shown with eight trips of a 7 ft. blade terracer drawn by the Caterpillar D2 tractor. The instructions given to the Soil Conservation Service in Kenya Colony as a result of considerable terracing experience are for 15

cuts to be allowed for a V-shaped channel with a minimum cross-section of eight to nine square feet, where a terracer with an 8-ft. blade is being used with a D.2 Caterpillar tractor or similar machine. On the other hand eight cuts are permitted for a 10 ft. blade used with a D.6 Caterpillar or similar tractor.

In Chapter Four, Dr. Maclagan Gorrie discusses the prevention of erosion in pasture by grassland management. It may be appreciated that owing to religious prejudices and the densely populated condition of many parts of India this is a question of the utmost difficulty and the author goes through the alphabet with a list of requirements for pasture and livestock inprovement which he says with truth "may seem a formidable list". Referring to the fact that "the top soil has all gone" (on hillside clearances) "and that the remaining subsoil is poor in nutrients but lack of water and/or aeration are more potent factors" the writer advises the conservation of water by contour ploughing and contour digging and various types of contour banks. He gives a list of the common fodder grasses which grow on Military Farms and on the Hissar Livestock Farm. Included in the list is *Heteropogon contortus* the "Spear grass" common in Ukamba and other parts of Kenya which is regarded as a pestilential grass of but periodic value but which, as "the commonest hillside cover in the Punjab", has to be used for hay by the Military Farms "after combing out the barbs on the standing crop with a machine". Most of the other grasses mentioned with the exception of Dub (*Cynodon dactylon*) and *Cenchrus ciliaris* are not known in East Africa. Amongst the introduced grasses mentioned in the report as under trial at the Institute of Plant Industry at Indore are a number of grasses from Africa including *Panicum maximum*, Kikuyu Grass (*Pennisetum clandestinum*) and Rhodes Grass, though the latter grass is erroneously named *Chloris virgata* which is an inferior grass of little palatability and value in East Africa.

Fodder trees and the use of loppings in the dry season are always of importance in areas where the stock population is high and the rainfall uncertain. In parts of India (Dr. Maclagan Gorrie states there are 3,000,000 buffaloes and 32,000,000 cows and bullocks in the Punjab and North-West Frontier Provinces) the pressure of the stock on the land is such that the lopping of trees has been for many years a major abuse. It is said in this report, for example, that "protection of Government property is so difficult that it has been seriously proposed that the Department gives up further attempts to grow kikar (*Acacia arabica*) on roadsides as it is impossible to protect it from lopping". It is suggested that villagers should be persuaded to grow thorn trees on their land or alternatively to form village societies for the protection of trees on common waste land. In order to save remaining oak and *Olea* forest from extermination the writer observes that Government will have to make some arbitrary decisions in cancelling rights of lopping.

The following list of fodder trees may be of interest to officers in the East African territories. Some of these trees are already known in East Africa for decorative or other purposes and it might be of interest for officers in some of the less favoured pastoral areas to try others of these trees for fodder purposes.

Species	Vernacular name
Acacia arabica (leaves and pods)	Kikar
Acacia modesta	Phulai
Acacia catechu	Khair
Albizzia lebbek	Siris
Bauhinia purpurea ..	Khairwal
Bauhinia variegata ..	Kachnar
Bauhinia vahlii	Malihan (creeper)
Butea frondosa	Dhak
Bombax malabaricum ..	Simal
Cassia fistula	Amaltas
Celtis australis	Batcar or khirk
Eugenia jambolana ..	Jaman
Grewia oppositifolia ..	Biul
Garuga pinnata	Kharpat
Melia azedarach	Bakain
Moringa oleifera	Sohanjna
Morus alba	Tut
Terminalia spp	
Olea cuspidata	Kao
Populus euphratica ..	Bhan
Zizyphus jujuba	Ber
Zizyphus nummularia ..	Malla

It is pointed out that when assessing grazing capacity (for which purpose it is suggested that plans should be prepared on a scale of four inches to the mile) available tree fodder should be included in the calculation, especially so that lopping may not be continued to a point at which trees are exterminated. It is worth bearing in mind indeed that pods and branches of various *Acacia* thorns play a very considerable part in maintaining livestock in some of the more arid parts of East Africa. This is a point which perhaps is not sufficiently considered when bush is being cleared during

grazing improvement schemes in certain of the native reserves. A more careful botanical examination of the bush and tree cover is frequently to be desired. The more modern method of tsetse control by thinning of bush coupled with the use of the new drug Antrycide, rather than complete clearance of bush, makes it all the more important that bushes and trees should be spared which yield fodder at times when the grass has been grazed out or is only capable of yielding a small amount of foodstuff to the stock.

Dr. Maclagan Gorrie deals at some length with "Water Conservation in Nature" and "Building up Soil Fertility". He refers to the fact that erosion occurs even under a forest cover if the canopy is insufficient to protect the soil from the rain, and to an experiment at Zanesville, Ohio, which shows the rapid increase in erosion following the decay of grass roots after ploughing in a grass ley. He draws attention to Dr. Bernard Keen's work on the drying out of soils and the self-mulching effect; but, as Dr. Keen has pointed out himself, this work was done on soils in temperate regions and tropical soils probably behave very differently. Indeed Pereira and Rayner at the Scott Agricultural Laboratories, Nairobi, have found that the effect of insolation is very marked even several feet down in coffee soils near Nairobi during the dry season and water vapour probably distils out of the soil for much greater depths than is the case in England.

"Major calamities" in the way of flood damage are foretold as the result of "the widespread destruction of Northern Indian Forests and particularly of the *Quercus* forests of the Dhauladhar of Kangra, the Simla hill states and the Murree and Abottabad Gallies, all of which lie in the heaviest monsoon altitudinal belt of 4,000 to 9,000 feet".

In his section on "Mulching" it is unfortunate that the author lumps together the mechanical effect of surface cultivation to give a "dust mulch" and the use of a vegetative mulch. Whereas the latter process has universal approval, the benefits of a dust mulch have been largely discredited for many years in scientific circles, except where it is believed desirable to fill in deep cracks in the soil which may cause evaporation of moisture to occur to a depth of several feet. Dr. Keen's own experiments and a whole series of experiments made in England, the U.S.A. and elsewhere have shown that the conservation of moisture in the soil is achieved by surface scraping to remove transpiring weeds, not by the dubious process of pulverizing the top few inches of soil to obtain an alleged effect of insulation and partial prevention of moisture movement from the soil into the air. Needless to say the conservation of moisture by the removal of all weeds and ground cover renders the soil specially subject to erosion in plantations and should not generally be practised during the period of heavy rains.

Diagrams and descriptions are given of masonry outlets and escape weirs "for dealing with surplus water especially from impermeable soils". These are built of stone or brick and not only act as safety valves for run-off from terraced areas, but also have value in retaining valuable soil on the fields. "On the other hand there will be many disappointments due to the ponding back of sterile sand if erosion is so severe that the valuable quota of fine top soil has already been removed. In Hoshiarpur they say that a Cho (ravine or gully) starts as gold and finishes as brass".

This manual was written for Government officers and others in the Punjab who are familiar with geography and conditions of the country. A reader who has never seen this land has to gather an understanding of the conservation problems in a somewhat piecemeal manner as he goes along. Possibly it would have been easier for the general reader if the manual had been separated into definite sections dealing respectively with erosion and conservation from the theoretical aspect; a description of the topographical, climatic, vegetational, geological, pedological, economic and sociological factors which promote soil erosion or conversely assist conservation in the Punjab; and lastly a description of the measures which can be taken to check erosion in various areas from the top of the catchments working down to the plains. Be this as it may, it seems necessary at this stage to pause, to come up metaphorically for air and to attempt to clarify our ideas of the situation in the Punjab.

It seems that overgrazing and an excessive amount of lopping and felling of trees in the mountains have increased the amount of run-off in serious measure. The worst storms occur during the monsoons in the foothills at altitudes of 2,000 to 9,000 feet. Every *nala* or ravine is frequently filled to capacity in whole sections of foothills. The greatest storm intensities probably are experienced at about 4,000 feet.

Conservation measures which are recommended include the reduction of run-off by the protection of cover on the watershed and by use of terrace banks or *wattbandi* on the arable fields which may be partially or completely levelled to increase the absorption of water. The surplus water is to pass off the fields by masonry or brick outlets or down grassed channels. The peak flows of the floods are to be reduced by the use of check dams. The uses of the latter structures built of brick or stone are summarized as—

(i) by direct storage of water and debris;
(ii) by acting as drops and thereby reducing the normal grade, thus restricting the velocity and reducing the silt-carrying capacity of the stream by making it drop its load of coarser sand;
(iii) by widening the channel and thus stopping deeper V-shaped cutting;
(iv) by increasing the wetted area and consequently increasing percolation and ground-water storage.
(v) by encouraging tree, bush and grass growth on this area;
(vi) by preventing further bank erosion.

As is customary under such conditions, the flood flows of the rivers or temporary water-courses are greatly in excess of the normal or dry-weather flows and the floods tend to produce sandy beds (which are sometimes several miles wide in the case of the main rivers), destroying in the process many hundreds of thousands of acres of good land. These large sandy wastes are additional sources of danger to the surrounding country in that the wind in some areas whips up the sand and drives it for several miles across the country, frequently forming dunes.

The sandy river beds tend to meander and destroy more land though "fortunately for the Punjab none of its major rivers behave quite so wildly as does the Kosi, which on its course from Nepal through the plains of Bihar, has shifted its course repeatedly within a pendulum swing of over 70 miles between Purnea and Darbhanga, laying waste some 3,000 square miles by dumping sand, blocking communications, spreading malaria and destroying crops".

In an estimate of "Reclaimable Land" in the Punjab, Dr. Maclagen Gorrie states that out of a gross area of over 60 million acres, 2,900,000 acres require terracing, 2,000,000 acres are badly ravined by erosion and require, he suggests, treatment by machinery. 6,200,000 acres are on the "desert fringe" with a rainfall of less than 15 inches per annum. Wind erosion is playing havoc here and incipient dunes are spreading into good ploughland. He advises the establishment of "a network of shelter belts and windbreaks" aided by a series of low-contour bunds made by machine. Where trees will not grow he recommends screens or windbreaks of the tall cane grass (*munji* or *sarkana*). A further 2,000,000 acres is available on the banks of ponds and streams and an estimated 2,355,000 acres on the borders of the main rivers.

A popular description is given of various types of heavy earth-moving machines including angledozers and bulldozers, carry-all scrapers and rooters. With the aid of these machines drawn or pushed by Caterpillar tractors it is stated that "in large blocks of ravines, 10 per cent of the area can be made cultivable fields at a cost of Rs. 50 (Sh. 75) per acre, provided only the *nala* bottoms are widened and bunded. If half the total acreage is attempted costs go up to Rs. 400 per recovered acre, whereas a cent per cent recovery in deeply ravined land will cost at least Rs. 800 per acre. For afforestation, of course, such elaborate levelling is quite unnecessary and the value of machine power lies in the facility with which waterholding bunds can be thrown up at intervals all down each *nala* bed. These cost estimates are based on performance at Kharian with two D8s, three D4s and two scrapers worked for a period of two months, for which machine-hour data has been kept. The teams worked in two shifts of five hours each".

It seems, however, that the writer is optimistic when he speaks of moving 6,000 cubic yards of earth for 120 rupees (Sh. 180, or cts. 3 per cubic yard!).

In a table working costs are given for Caterpillar tractors of various types. These costs are given at the end of this article in East African shillings and cents at the rate of Sh. 1/50 to one rupee, together with the comparative figures for D6 and D7 Caterpillar tractors according to the Soil Conservation Service of the Department of Agriculture, Kenya Colony.

It appears, on the criterion of the experience of the Soil Conservation Service of the Department of Agriculture in Kenya Colony, that considerable under-estimates were made in the Punjab figures for the cost of running tractors, particularly in allowances for spares and other miscellaneous expenses inseparable from the working costs.

Setting aside this question of difference of opinion with regard to the cost of operating tractors, it must be considered that the decision as to how much money can be spent on reclaiming eroded land will depend not only on economic questions but on the political outlook and the degree of population pressure on the land. Nevertheless, politics cannot always float ethereally in a non-economic world, and whether in East Africa or in the Punjab some passing glance must be made to the question of the total amount of loan funds available, the state of the general revenue and the possibility or improbability of being able to milk the taxpayers still further in the interests of the overcrowded peasantry, whether these taxpayers are composed of the more prosperous part of the local population or the long-suffering and comparatively blissfully ignorant taxpayers several thousands of miles away overseas.

A major trouble in the Punjab is the destruction of good land on the sides of the rivers and the streams by the devastating floods which rush down from the foothills of the Himalayas during the rainy season. This question was mentioned earlier, together with Dr. Maclagan Gorrie's estimate that nearly four and a half million acres might be reclaimed from these strips, bordering on the rivers, which are occasionally subject to floods. This phenomenon of the raising and widening of river beds accompanied by the dumping of large quantities of sand and silt is not unknown in East Africa and may be said to occur on a minor scale on all rivers which run through the semi-arid areas of the East African territories. One can call to mind, for example, the wide bed of the River Tiva in the Kitui District of the Ukamba Reserve. For the most part, however, the rivers in East Africa are not impressive in volume owing, it is presumed, to the considerable quantities of water which sink into the land to augment the water supplies at depth. For this reason there could only be opportunities in a relatively minor way—fortunately it may be considered—for employing the techniques which are suggested by the author of this manual for the canalization of stream and river beds and the reclamation of land by mechanical means, such as by the building of jetties or groynes, and by vegetative means, such as by the planting of hedges, trees and coarse grasses to make protected zones along the stream banks in which the velocities of flood water will be retarded and the deposition of silt increased. Nevertheless, there must be areas in East Africa where such work might be beneficially carried out, even on a small scale, in order to protect good agricultural land which is continually being eaten away by rivers in spate, and to reclaim land which is at present only of partial value to the local inhabitants. For this reason, many officers of the Agricultural Departments in the East African territories would find it useful to have a copy of this manual in their station libraries although it is hardly necessary to say that local materials, local trees, shrubs and grasses would have to be substituted when employing these techniques.

There is also discussion of the employment of windbreaks and of various hydrologic data which should be of interest and value, if suitably adapted, to many officers in East Africa.

In a paragraph regarding strip cropping Dr. Maclagan Gorrie quotes the reviewer in a short article written on this subject in this journal more than nine years ago. The actual article quoted strip intervals recommended in Nebraska, Kansas and Oklahoma as follows: "(*a*) Slopes 0 to 2 per cent: minimum of 25 to 50 feet in erosion-resisting crops and 100 to 150 feet maximum in row crops; (*b*) slopes 2 to 3 per cent: minimum of 40 to 50 feet in erosion-resisting crops and 75 to 125 feet maximum in row crops; (*c*) slopes too steep for terraces: 50 per cent of the land area should be in permanent or semi-permanent erosion-resistant crops. The clean-tilled strip should not exceed 100 feet in width".

The author of this manual goes on, however, to quote the present reviewer as having said "no land with a slope of more than 12 per cent or 1 in 8½ gradients should be brought under any form of cultivation. Lands with a slope of more than 3 per cent or 1 in 33 gradients are too steep for terracing". It can only be assumed that this quotation was from some correspondence and that there was a typographical error which escaped notice as "terracing" should obviously have been "strip cropping". This error is the more unfortunate as Dr. Maclagen Gorrie comments that "in fixing the reserve gradient Government should not overlook the fact that other countries with greater knowledge than we have regarded 3 per cent as the highest gradient which allows land to be cultivated". It is highly unlikely that any country is fortunate enough to be able to refrain from using land for agricultural purposes which is steeper than this and there is, of course, a great deal of land

with a slope of over 12 per cent which is cultivated—in parts of East Africa, such as Bugishu, up to 100 per cent—although 12 per cent is the limit for the use of terraces which may be maintained readily by means of ploughing. On gradients steeper than 12 per cent it is generally necessary to maintain terraces by hand, while on slopes over 18 per cent or 20 per cent some form of bench terracing is frequently used to retain the soil on hillsides, although portions of hillsides may be cultivated as mentioned above if only, say, 50 per cent of the area is cultivated in contour strips.

In the latter portion of the manual the writer gives details of a suggested "land use" classification which is obviously based on the U.S.A. model and mentions the value of the use of air photos and the advantages of mosaics, prepared off aerial photos, over ordinary survey maps.

At the end of the manual is quoted as Appendix II "Punjab Land Preservation (Chos) Act, 1900 (Punjab Act II of 1900), as modified up to 1st July, 1944". This legislation has certain points of similarity to the Land and Water Preservation Ordinance in Kenya Colony, but it is noteworthy that the penalty for offences under the former Ordinance only extends to "Imprisonment for a term which may not exceed one month" or "A fine which may extend to 100 rupees" or both. These do not sound very frightening deterrents.

The aspect which struck the reviewer was that this manual pays little attention to the human side of the erosion problem in the Punjab. It is plain that the evils of overgrazing, over-cultivation, over-lopping of trees in catchment areas, and over-stocking generally, are all the result of the social and economic customs of a people whose rapid multiplication and pressure upon the land merely mirrors what is happening in many other parts of India also, so that this subcontinent has become a warning and a gloomy example to the rest of the world. Nevertheless, little is seen or heard in this manual of the Punjab citizens and peasants other than a few somewhat military-looking figures, presumably of local officials and employees, posing stiffly in some of the numerous photographs in the book. There is, it is true, a brief mention of the fact of the tenancy customs which are "apart from the grazing problem the greatest single stumbling block which prevents progress". Sharecropping in the Punjab has the usual evil results on the land which this system, by which the cultivator has but a transient interest in the fertility of the soil, has in many parts of the world amongst men of any colour. "The usual custom of *batai*," says Dr. Maclagen Gorrie, "that is the landlord taking half the grain and allowing the tenant possession for only one crop, is responsible for much bad cultivation. There is no incentive to improve the field by terracing, levelling or *watt-bandi*, and, in fact, improvement by the tenant himself is often followed by eviction and the land is given to another who can afford to pay a higher rent. This, of course, only happens with tenants-at-will (*ghair maurusi*). The more privileged class of occupancy (*maurusi*) tenants cannot be evicted except as the result of a civil suit, but in many districts the natural enmity between tenants and landlords discourages any effort by either to improve the land itself."

It is clear that flood damage can be prevented most easily and economically if the conservation problem is dealt with first on the top of the catchments on the mountains and on the foothills before efforts are made to control the rivers and streams on the lands below. This is no obscure technicality, it is just plain common sense. It seems that it is more difficult for people to appreciate that deteriorated land cannot be permanently improved nor further agronomic maladjustments prevented if attention is merely paid to the results and to *ad hoc* measures for the amendment of these ailments rather than to the causative factors which lead to the misuse of natural resources and the destruction of soil and water supplies over wide areas. Giant bulldozers can send tons of sand crashing into the gaping "chos", thousands of miles of terraces may be made by tractor, by straining ox and by sweating peasants; millions of new trees may be replanted on the threadbare hills; but if the basic causes of the conditions which it is being attempted to remedy are not removed, then thousands of lakhs of rupees could be poured into the land without there being any change being made which would be still perceptible in a few years time.

What are these basic causes? In the Punjab, as in the Balkans, the southern States of the U.S.A., the reservations of South Africa, the scarred mountainsides of China and in the native areas of East Africa, the cause must be the sum or interaction of several factors: the increasing population pressing upon the land—no unfamiliar theme these days and even becoming a familiar hair-raiser in popular magazines and newspapers; the poverty of a

large part of the population; and the unbalance of the economy of any country where industrial development is tardy, whether due to lack of suitable local materials or just to sheer backwardness and ignorance.

It is questionable whether the neglect of the economic and sociological aspects in so many discussions of soil conservation problems is due to too narrow a conception of the field which a soil conservationist should cover; or whether it is due to the fact that administrators in the past have discouraged the officers of technical branches of Government, by mere disregard or by more direct snub, from interesting themselves in that wider area of human associations which were apt to be grouped vaguely and comprehensively, as an esoteric activity in which administrators alone were concerned, under the title of "Politics".

This attitude is largely being broken down in East Africa by the discussion of conservation and development problems in native areas by district and provincial teams in which members of all interested departments take an active part. Possibly it remains to dissipate any remainder of that attitude of mind amongst technical officers which is exemplified by a visiting scientist in Kenya some years ago who advised the complete depopulation of a large part of Ukamba in order to allow nature to restore the soil by a reclothing by vegetation for several years. When asked where the "displaced persons" were to go he dismissed the question airily as an administrative problem which did not concern him.

As Charles E. Kellogg points out in his book "The Soils that Support Us": "The physical problems of water and erosion control, difficult as they are, frequently are far easier than the economic and social problems involved in making conditions such that it is possible for the farmer to follow good practices".

ESTIMATES OF TRACTOR COSTS, PUNJAB, AND SOIL CONSERVATION SERVICE, KENYA COLONY

WORKING COSTS PER YEAR

	D.7 Caterpillar Diesel			D.6 Caterpillar Diesel		
	Punjab	Kenya (S.C.S.)		Punjab	Kenya (S.C.S.) Series 4R, 5R	Kenya (S.C.S.) Series 8V
	Sh.		Sh.	Sh.	Sh.	Sh.
Diesel fuel, 3 gals. ..	5·63		5·60	2 gals. 3·75	2·1 gals. 2·45	3 gals. 3·51
Petrol, ⅛ gal. at Sh. 3	0·38			0·38		
Lubricant oil 1·10 gal. at Sh. 9	0·90		1·50	0·90	1·00	1·00
Grease	0·18			0·18		
Operators, cleansers and maintenance ..	1·50		2·92	1·50	2·20	2·26
TOTAL	8·59		10·02	6·71	5·65	6·77
FIXED CHARGES PER YEAR						
Depreciation	3·90		5·60	3·50	3·33	3·75
Repairs	1·95	Spares	6·00 (or 8·50)	1·50	Spares 3·50	3·50
		Mechanic's time ..	0·50	—	0·50	0·50
		Mechanic's travel.	0·50	—	0·50	0·50
		Transport of Diesel	0·60	—	0·40	0·40
		Travelling between jobs	0·90	—	0·65	0·65
Interest on investment at 4 per cent. ..	0·15		—	0·15	—	—
TOTAL	6·00		15·35	5·15	8·88	9·30
GRAND TOTAL ..	14·59		25·37 (or 27·87)	11·86	14·53	16·07

Note to Estimates of Tractor Costs, Punjab, and Soil Conservation Service, Kenya Colony

Punjab figure of depreciation based on writing off over 10,000 hours, Kenya figure over 15,000 hours with complete overhauls at 500 and 10,000 hours.

The Punjab figure for repairs is based on half the original cost of the tractor spread over 10,000 hours; the Kenya figure is based on actual costs.

The Punjab figures appear to include the use of an angledozer. An extra Sh. 2 an hour is charged by the Soil Conservation Service, Kenya, to cover depreciation and spares of the angledozing equipment.

The heavy wear on tractors (especially on tracks) which are used on earth moving, such as dam building, has led to a higher charge being made in Kenya—Sh. 8/50 an hour for spares for D7 tractors.

NUTRITIONAL EXCESSES IN SISAL

I—SUSCEPTIBILITY TO WEEVIL IN MATURE SISAL

By J. E. A. den Doop*

(*Received for publication on 15th June*, 1949)

More than thirty years ago, the author's first research assignment in sisal was the investigation of the sisal weevil. This beetle species belongs to the family *Curculionidæ* and within this family in the genus *Scyphophorus*. This genus consists of two known species only. One of these is confined to California and breeds in *Liliaceæ*, e.g. Yuca species, but not in Agavæ. The other is endemic in Mexico but has emigrated to virtually all tropical countries where sisal is grown. Most probably it has been brought to these countries in planting material of sisal and possibly of other agave species.

The priority name of the Mexican weevil species is *Scyphophorus interstitialis Gyll.*, though usually the name *Sc. acupunctatus Gyll.* is used. The fact that one author has described this weevil species on two occasions under two different names seems to have caused some confusion as to whether there exist two species of Agave weevil or only one. Actually, one only exists. In Mexico it not only lives in sisal, which is *Agave sisalana Perrine*, but also in other Agave species as well as in other genera of the *Amaryllidaceæ* family, in which the genus Agave belongs, and also in some species of the *Liliaceæ* family.

The Agave weevil is more completely adapted to some other Agave species than to sisal, viz. to such species as are more sugary and as contain less organic acids in the free stage and less saponins. In Agave species of a high sugar content and with a low saponin content, the Agave weevil can breed through the whole life cycle of the plant, if the latter is growing in a climate suitable to the weevil. The reason why such Agave species suffer little or not at all from the Agave weevil is that they are adapted to high altitudes, where it is too cold for the Agave weevil. The latter feature may also be the reason why the Agave weevil does not occur in the high-level sisal plantations of Kenya.

While studying the life cycle of the Agave weevil in Java more than 30 years ago, the author found that at low-level sisal plantations the organic-acids content in sisal is probably the most effective limiting factor in the adaptation of the weevil. Furthermore, the low sugar content of sisal is apparently of importance. The content of saponins is rather low in sisal, very much lower than in the *Lechuguilla* species, for example.

The main organic acids in sisal are malic, citric and succinic acid, while others such as oxalic seem to be important occasionally. These acids play a significant part in the physiology of the sisal plant with its semi-succulent constitution. Malic acid, for example, is an integral factor in the carbohydrate synthesis of succulents.

It should be remarked, however, that in sisal, organic acids occur not only in the free state but mostly combined with calcium, magnesium, potassium, etc. Together with these bases, the acid radicals do not contribute to the apparent acidity of the sisal tissue, or at least to a lesser extent than they would in the free state.

The attitude of the weevil towards the sisal plant in its stages of development and within these stages towards the various organs of the sisal plant is mainly determined by the free acidity of the sisal tissue. Generally speaking, those parts of the sisal plant are least acid which are in the meristematic stage of development, i.e. in the stage in which cell division takes place abundantly. All those parts of the sisal plant of any age which are conspicuously fibrous have definitely passed the meristematic stage. Therefore, normally, no weevils will be found breeding in green leaves or in the higher sections of the leaves, still in the central bud. The meristematic tissue in sisal is found there, where the leaf bases combine with the top of the bole. In very young nursery plants almost any part of the future bole is meristematic. Therefore, these preliminary boles, sometimes called bulbs, are the most attractive normal sisal organs for the weevil. When the nursery plants grow older, their bulbs become less and less attractive to

* Tropical-Crops Research, P.O. Box 227, Times Square Station, New York 18, N.Y., U.S.A.

the weevil until at an age of about one year, vigorously growing nursery plants will be left alone by weevils, at least the latter will not breed more in their bulbs. When such nursery plants are transplanted into the field, they undergo a kind of physiologic shock, which now makes them attractive to the weevil, which will again breed in their bulbs. However, after one year of vigorous growth in the field, normal young field plants will be avoided by weevils as a breeding ground.

In normal mature field plants, the weevils confine their damage to boring into the bases of those leaves which are still in the central bud. It is these bases, which are nearest the meristematic tissue and which are being elongated in the growing process. However, in normal, mature sisal plants, the weevils will not breed within this meristematic tissue.

Of course, as always in nature, there is quite some variability in the occurrence of the features just described. So, if a nursery is badly overgrown by weeds, the nursery plants will stay susceptible to weevil breeding longer than normal. The same may happen in young sisal fields.

A feature more or less frequent in nursery plants is the drilling of holes, the size of weevil width, through their central bud. Afterwards, one finds these holes in the outgrown leaves at varying distances from their leaf bases, according to the age of the undeveloped leaves at the time of the hole drilling. Also in young sisal fields, this hole drilling may occur normally to some extent.

When a weevil breeds in a nursery plant, it is seldom that more than one adult weevil will hatch from a single nursery plant. In young field plants, the number of adult weevils hatching from a single plant may be as many as five, seldom more. Consequently, only in the case of very serious infestations is the multiplication of the weevils proceeding fast in nurseries and in young sisal fields.

However, large numbers of weevils, normally, may develop in old sisal boles. When all the leaves have been cut from a poling sisal plant, while the flowering pole has been cut away at an early stage of its appearance so that the bole has not dried out, the latter may remain in a fresh condition for a considerable period of time, but sooner or later rotting of the bole tissue will set in, caused by bacteria. By their exudations, these bacteria change the sap of the bole tissue from an acid to a neutral or approximately neutral reaction. At this stage, weevils, if present in the corresponding sisal field, will start breeding in the rotten bole tissue. According to the spreading of the rotting process within the bole, the weevils will multiply and eventually hundreds of adult weevils may hatch from one single bole. It is easily seen that this opportunity for weevils to multiply is much greater than in nursery plants or in young sisal fields. In Java the author has seen more than 60 per cent of the plants in sisal nurseries destroyed by adult weevils, mainly coming from surrounding fields which contained many rotting boles.

Thus far, weevil breeding has been envisaged only in as far as it occurs under normal conditions of susceptibility of the sisal plants. However, in East Africa, sisal areas are known to occur where the infestation with weevils is abnormally heavy, and where mature sisal plants are infested by breeding weevils. Even on the grounds of the sisal experimental station at Mlingano in Tanganyika, sisal is well known to be abnormally infested with weevils.

When in 1948 the author began to study this abnormal sisal infestation, he heard at various occasions the opinion being expressed that the cause of this abnormal susceptibility on the grounds of the experimental station was the presence of many non-sisal Agave species and of hybrids between couples of various Agavæ, which are more susceptible than sisal. However, soon, the author met a place with very severe weevil susceptibility in mature sisal, where no other Agave species than *A. sisalana* and no hybrid Agavæ were to be found for many miles around. Consequently, he put aside the theory of other Agave species and hybrids as the cause of abnormal susceptibility in mature sisal.

However, wherever the author found weevils breeding in the bole of a mature sisal plant, he found some or all of the leaf bases of such plant affected by a necrosis or clearly having been affected by a necrosis. That the occurrence of the necrosis had not secondarily been caused by the weevils but was a primary feature by itself was proven by occurrence of leaf-base necrosis that was not associated with weevil breeding. Therefore, it occurred to the author that leaf-base necrosis might offer an opportunity to the weevil for breeding in mature sisal.

At this stage of the discussion it seems proper to consider in more details the feature of leaf-base necrosis in sisal. Afterwards, its association with weevil breeding will be taken up again.

It may well be inserted here that leaf-base necrosis is a feature, very distinct from the symptoms of potassium deficiency, called "banding disease" in East Africa. The latter symptoms never initiate in the leaf base but always in the lower part of the leaf blade. In this part of the leaf blade, the first symptoms of potassium deficiency may be black patches or black margins. These patches and/or margins may gradually spread through the whole width of the lower leaf-blade part, so as to form a band across the leaf blade. Subsequently, the leaf may collapse at the necrotic place.

In very severe cases of potasium-deficiency necrosis, it may spread from the lower part of the leaf blade into the leaf base. Similarly, in very severe cases of leaf-base necrosis, this may spread above the leaf base into the lower part of the leaf blade. Eventually, in such cases, it may become difficult to distinguish with the eye between such symptoms of leaf-base necrosis and of potassium-deficiency necrosis. However, in their initial stages they all have been unmistakably distinguishable with the eye. Of course, chemical analyses can decide such difference on all occasions.

It also may be remarked here that sometimes, as in potassium-deficiency necrosis, so in leaf-base necrosis only part of the width of the affected leaf section becomes necrotic, the unaffected sections remaining perfectly normal to the eye.

In the past, the author had come across various infestations of sisal fields with leaf-base necrosis. He first observed such infestation after the eruption of the volcano Kloet in Java, in May, 1919. With this eruption, the soil of many thousands of acres of sisal fields was covered with a layer of volcanic ash, varying in thickness from less than an inch to more than 6 inches. Some time after the eruption a small proportion of the sisal plants began to exhibit the symptoms of leaf-base necrosis. Usually the affectation was confined to a bunch of a few of the leaves on every affected plant. Sometimes a considerable number of leaves in one plant were affected. Only rarely were all the leaves of one plant, inclusive of those in the central bud, simultaneously affected. In the latter case, the affected sisal plants died. In the other cases, usually after the first attack no further leaf bases became necrotic in the same plant.

The author studied the effect of mixing the layer of volcanic ash with the original top soil on the incidence of leaf-base necrosis in field plots. He found this mixing to cause a slight, though significant, increase in the incidence of leaf-base necrosis. Then, analysing the volcanic ash, it appeared that it contained large amounts of easily soluble inorganic plant nutrients especially potassium, but nitrogen was virtually absent in the ash. Thereupon, the effect of nitrogenous fertilizers was studied in field plots with volcanic ash and it was found that such fertilizer applications completely checked the appearance of new cases of leaf-base necrosis, while without these the affectation continued to appear in new plants.

However, the frequency of such new appearances now soon began to decline and within two years from the volcanic eruption, had faded out completely.

It is clear that at the described occasion, the abundance of various inorganic plant nutrients in the volcanic ash in the absence, however, of nitrogen had originated a disturbance in the balance of plant nutrients in the soil solution and that consequently the nutritional balance within some of the sisal plants had seriously been disturbed, with leaf-base necrosis as a result. Subsequently, apparently, the disturbed balance had been restored by natural mixing of the ash nutrients with those of the original soil and by simultaneous development of available nitrogen by micro-organic activities.

The reason why only in a small proportion of the sisal plants leaf-base necrosis made its appearance should be attributed to quantitative variation within each of the causative factors. Apparently, only in the concurrence of extreme variations in a few of these factors was the physiologic disturbance within the sisal plants great enough to cause leaf-base necrosis. The frequency of such concurrence, of course, diminishes fast with increasing numbers of the required factors involved.

A few years after his first contact with leaf-base necrosis in sisal, in another part of Java, the author came across another wide-spread occurrence of leaf-base necrosis. In this case, an alluvial soil was covered with a large number of termite heaps. By its nature, this soil was rather poor in nitrogen, even immediately after the clearing of the forest.

Also, it was badly adjusted to a natural renewal of its nitrogenous supply by micro-organic life. After the clearing of the forest, the sisal on this land was planted during the first rainy season. Until the next rainy season, the sisal plants would show nothing unusual. Then, however, during the second rainy season of their life cycle, many of those plants growing in the lower sections of the termite heaps began to exhibit leaf-base necrosis in varying degress of intensity, ranging from a bunch of a few leaves in a plant to the complete collapse of the whole plant in a short time. During each of the few following years in the rainy season, new cases of leaf-base necrosis appeared in plants, growing in the same sections of termite heaps. However, in each following year the frequency of additional leaf-base necrosis diminished sharply and vanished virtually completely four years after the planting of the sisal. Simultaneously a severe nitrogen shortage had developed in the least fertile parts of the fields, especially in the areas between termite heaps. In the lower sections of the termite heaps, however, the nitrogen supply was still sufficient. It was demonstrated analytically that, after the clearing of the forest, the soil in the lower sections of the termite heaps contained far more available nitrogen than in any other part of the fields; that, however, soon thereafter a fast decline of this nitrogen content set in.

What had happened in this case may be summarized as follows. The termites had accumulated large amounts of organic matter in the termite heaps. After the clearing of the forest, this organic matter had decayed rapidly and large quantities of nitrogen had been freed in available form. By water percolating through the termite heaps, this available easily movable nitrogen accumulated in the lower sections of the termite heaps. Other plant nutrients such as phosphorus, potassium and magnesium, which do not move so easily as nitrogen with percolating water through the soil, could not accumulate so fast as the nitrogen in the lower sections of the termite heaps. Consequently, the proper balance between plant nutrients in these places broke down and a surplus of available nitrogen disrupted the physiology of the sisal plants growing in these places. Hereby, leaf-base necrosis was provoked in a considerable number of such plants. Subsequently, the rapid destruction of organic matter in the termite heaps depleted the organic matter to such an extent that during the course of five years from the clearing of the forest the current of available nitrogen towards the lower sections of the termite heaps had become normal again, while the proper balance between the various plant nutrients in these sections was restored.

The total proportion of sisal plants affected by leaf-base necrosis in the fields, during the four years of its prevalence, was 4 per cent of all the plants in the whole fields. In the lower sections of the termite heaps, however, this percentage reached in some places as high a value as 60 per cent.

Again a few years later, in 1932, after the author had established in Java the practice of inundating the sisal fields at the time of their rotation with the effluent of the sisal factory, a new case of leaf-base necrosis made its appearance. It was observed in those patches of the effluent-treated sisal fields where abnormally large quantities of sisal waste had accumulated. The course of appearance and of disappearance of the incidence of leaf-base necrosis, in this case, was very similar to same as in the case of the lower termite-heap sections. Apparently in this case the course of incidence was determined by a very rapid decay of the accumulated sisal waste which slowed down later. Whether in this case the nutritional disbalancing was effected by an excess of available nitrogen was not proved, but is probable.

In the middle of the 1920's, the author had studied the effect of very liberal applications of single chemical fertilizers on the appearance of leaf-base necrosis in field plots. It appeared that in certain alluvial soils, leaf-base necrosis could be provoked experimentally by large applications of either nitrogen, phosphorus, potassium or lime as commercial fertilizers. The incidence of the leaf-base necrosis provoked was not large under the given experimental conditions but quite significant.

Also, it was observed that in certain soils, leaf-base necrosis would develop in such sisal plants as were growing on the margins of drainage ditches, where mud was periodically deposited, dug from the ditches, where it had accumulated by surface erosion from the fields. Apparently, in this case, easily movable plant nutrients had landed in the drainage ditches and were supplied to the marginal sisal plants in the operation of cleaning the

ditches. Hereby, apparently, the proper nutritional balance of the soil around the marginal sisal plants had broken down. Chemical analysis of many soil samples in corresponding field plots confirmed the above deductions.

It will now be appreciated that the author, armed with this accumulated knowledge of leaf-base necrosis and observing in East Africa weevil susceptibility in mature sisal to be associated with leaf-base necrosis, was vividly aware of the possibility that a nutritional excess in the affected sisal plants might play a role in the weevil susceptibility. At the same time, with the author's experience of the effect of the grade of acidity in sisal tissue on its palatability for weevil grubs, naturally, he considered it important to investigate the acidity conditions of the necrotic parts of affected sisal plants and of all such parts as were found infested with weevil grubs. What he discovered was the following.

In all those cases, where the bases of all the leaves of a sisal plant were necrotic, the necrotic parts were very alkaline, i.e. of a pH considerably higher than 7. A sharp reaction-boundary was met between necrotic tissue and such tissue of the same leaf as had a normal, green appearance. While the former was very alkaline, the latter was acid as about in normal sisal leaves, viz. with a pH of 5 to 6. Virtually all those plants, which were affected with alkaline leaf-base necrosis, were severely infested with breeding weevils of various stages of development. In a few cases, where sisal only a couple of years old, was affected with severe leaf-base necrosis of the alkaline type, the necrosis was not, or more likely not yet, associated with breeding weevils.

The weevil grubs in their infestation, are confined within the alkaline tissue and stop their attack at the boundary of the acidic tissue.

It is the author's opinion that for a sisal plant, affected in all its leaves with alkaline leaf-base necrosis, it is of little importance whether weevils invade it or not because such plant is condemned to die soon anyway. However, in regard to the frequency of weevil occurrence in a sisal field, the incidence of leaf-base necrosis is very pernicious because the latter incidence is apt to raise the weevil frequency enormously. This will be appreciated, if it is visualized that affected sisal plants each may produce hundreds of adult weevils. The severest case of alkaline leaf-base necrosis met in East Africa by the author was about 6 per cent of the total sisal population in the affected field. If in such a field every affected plant delivers 200 adult weevils only, there will be twelve times as many weevils as there are sisal plants. This means a rich source of infestation especially for adjacent young sisal fields and even more so for near sisal nurseries.

The alkaline type of leaf-base necrosis did not appear to be confined to leaf bases, but was also found in a few newly emerged flowering poles. The corresponding patches of necrotic tissue occurred near the bases of the flowering pole, and were infested with weevil grubs.

Alkaline leaf-base necrosis was also found in what the author used to call bud-base necrosis. To a small extent, bud-base necrosis is met in normal sisal fields and somewhat more frequently in normal sisal nurseries. In fields found infested with leaf-base necrosis bud-base necrosis occurs abnormally frequently. In East Africa, in sisal fields with the alkaline type of leaf-base necrosis, the bud-base necrosis was also found to be of an alkaline reaction and weevils were found breeding in the necrotic bud section. Weevil bore-holes were frequently found associated with bud-base necrosis.

It is the author's opinion that the frequency of alkaline bud-base necrosis in young sisal fields might be utilized advantageously as a criterion of unbalanced nutritional conditions of the soil concerned. It also may be utilized as a criterion in studying unbalanced soil conditions in experimental field plots.

The East African soils, where the author met incidence of alkaline leaf-base necrosis, were acidic, with a pH of about 5 to 6.5. However, at least one exception was met, in a case of alkaline necrosis in a sisal bole growing in a field with outcropping coral stone, where the soil had an alkaline reaction.

With a view to the author's experience with a variety of nutritional excesses being capable of provoking leaf-base necrosis, one should be very careful in deductions regarding the exact nature of the nutritional disturbances which cause leaf-base necrosis associated with weevil susceptibility. There may well exist a variety of such disturbances. Later, in this article, an experimental one will be described.

First, however, another type of weevil susceptibility in mature sisal will be discussed.

While the author was testing the reaction conditions of the necrotic sections in naturally occurring leaf-base necrosis, he found in a small proportion of the cases a severe acidity instead of alkalinity. No weevils were found associated with such acidic, necrotic leaf bases, if the necrosis was of a recent appearance. However, in those cases where the acidic necrosis was old and where around the bunch of dried-out, formerly necrotic leaves, a section of the sisal bole had decayed, weevils were found breeding in the decayed bole tissue. The bases of the formerly necrotic leaves had completely dried out but were otherwise intact; no weevils had bred in them. All the weevil breeding occurred in the decayed bole tissue around the formerly necrotic leaf bases. The decayed bole section was quite distinct from the main body of the bole. The latter, together with the fresh looking leaves, did not exhibit any abnormal symptoms at all. The decayed tissue with the breeding weevils was of an approximately neutral reaction, i.e. it had a pH of about 7.

Apparently the rotting of the decayed bole section had been induced by the acidic leaf-base necrosi. Though the affected leaf bases themselves remained acidic, the rotting tissue around them attained a neutral reaction by the exudations of the decay bacteria and thereby readied a limited breeding ground within the bole for weevils.

The appropriateness of the above explanation of weevil susceptibility, as indirectly caused by acidic leaf-base necrosis, was very clearly confirmed by the following case. A sisal plant of good size which had already been cut a few times, and which had quite a good new crop of leaves, showed a bunch of seven leaves with rather fresh leaf-base necrosis. The necrosis appeared to be of the acidic type. No weevils were found associated with the necrotic leaf-bases. However, within the cut area of the bole, four dried-out old leaves had been left uncut. They clearly showed that they had formerly been affected by leaf-base necrosis. It was apparent that the dried-out condition of the blades, resulting from the necrosis in the bases, had induced the cutter to leave these four leaves uncut. Around the formerly necrotic leaf-bases, the bole was decaying though, apparently, the decay remained confined within a definite section of the bole. Within this decaying bole section, weevils of varying stages of development were found.

It appears, therefore, that the bole decay, secondarily induced by a confined number of necrotic leaf-bases, can be checked by the surrounding healthy bole tissue and thus remains confined to a restricted section of the bole. Simultaneously, it appears that this cycle of events can occur at least twice in the same sisal plant.

By now it is clear that two types of susceptibility for weevils in mature sisal exist, an alkaline and an acidic type. The alkaline type, usually, develops simultaneously in all the leaf-bases of a sisal plant, inclusive of the bases of the undeveloped leaves in the central bud. This type, which also in the absence of weevils would be destructive of the sisal plant, is nearly always associated with a very severe infestation by breeding weevils. Even in such plants the weevil grubs will not touch those sections of the leaf blades which remained acidic; in fully grown leaves this is virtually the whole leaf with the exception of the leaf-bases. The alkaline type of necrosis was also found in the lower section of a few freshly flowering poles and also in very many cases of bud-base necrosis. In East Africa the acidic type of leaf-base necrosis seems to be nearly always confined to a restricted number of leaves within an otherwise healthy looking sisal plant. Weevil breeding is associated indirectly with the acidic type in as far as the breeding occurs in the decaying bole tissue, around the necrotic leaf-bases. The sisal plant has the power of inhibiting this decay to spread outside a rather restricted bole section around the necrotic leaf bases. The decay of the bole section, apparently, is induced by the necrotic leaf bases.

It has already been mentioned that so far the alkaline type of leaf-base necrosis was observed by the author in East Africa mostly, though not exclusively, in acidic soils with a pH ranging from about 5 to 6.5. The acidic type of leaf-base necrosis was observed not only in acidic soils, where the alkaline type of leaf-base necrosis was prevalent, but also in soils ranging in acidity from a neutral to an alkaline reaction.

The acidic type of leaf-base necrosis is the one that induces the abnormal weevil susceptibility in mature sisal on the grounds of the experimental station at Mlingano.

In Tanganyika, as formerly in Java, the author found experimentally that various

chemicals can provoke leaf-base necrosis in sisal plants. Virtually all these necroses were of the acidic type. The author had not the opportunity to observe these plants long enough for checking, whether in these cases secondary susceptibility for weevil breeding is induced by the leaf-base necrosis. Therefore, most of these cases will not be considered further.

However, the East African case history of two instances of experimentally provoked leaf-base necrosis will be reported. In these instances two sisal plants were treated with rather fresh bat manure. In one plant, the bat manure was applied in two holes, drilled with a carpenters drill in that bole section of the plant where previously the leaves had been cut. About six weeks later, on this plant, a bunch of five leaves showed the acidic type of leaf-base necrosis. No weevils, yet, were found associated with this acidic leaf-base necrosis.

In the case of the second sisal plant, the bat manure was mixed with the soil around the sisal plant. In this plant, all the leaf-bases and the whole base of the central bud were affected by a severe necrosis of the alkaline type. Soon, the necrotic sections of this plant were infested with a large number of breeding weevils.

From the example of bat manure it will be seen that one and the same substance can cause both types of leaf-base necrosis, depending upon how the substance is applied to the sisal plant. Of course, in the first instance the sisal plant had to digest the bat manure whole, whereas in the second the sisal roots had a chance of making a selection from the various constituents of the bat manure.

It now will be understood that no hard and fast rule can be given for the cause of leaf-base and related necroses and similarly for the abnormal susceptibility for weevil in mature sisal. However, it need not be doubted that the cause is an abnormal physiologic condition in the sisal plant, which has its severest effect in the meristematic tissue of the leaf-bases and of the base of the central bud, while also the base of freshly developing flowering poles may be affected. Apparently, this abnormal physiologic condition results into a breakdown of the normal balance between the soluble cell constituents, whereby eventually the cell-sap reaction deviates either to an extreme alkaline or to an extreme acidic composition. Furthermore, it need not be doubted that the necrosis-causing abnormal physiologic condition in a sisal plant has its origin in an abnormal nutritional condition in such plant and consequently in the soil in which the plant grows.

However, it is also quite clear that a variety of abnormal nutritional conditions in the soil are able to induce tissue necrosis, either of the alkaline or of the acidic type. Therefore, the problem of how to correct such abnormal nutritional condition in a given soil, is a problem by itself, which may vary considerably between various soils. Consequently, this problem has to be studied separately for each soil.

The study of such a problem is not an easy one. In the case of a simple deficiency disease, as e.g. potassium deficiency in banding disease, one needs only apply single chemicals as e.g. nitrogenous fertilizer alone, phosphoric fertilizer alone, potash fertilizer alone, etc., in various field plots of a simple design. Subsequently, the effect of the added chemical missing in the soil will easily be observed. However, when the nutritional abnormality to be corrected is an excess of some plant nutrient, the correctional problem is of a vastly more complex nature. First of all, one has to find out what nutrient is excessively being absorbed by the sisal plants. Having discovered this one cannot correct this abnormality by eliminating the excess from the soil. This might be possible in a small laboratory sample but not under field conditions. One can do nothing else than buffer the soil against the excess by the application to the soil of other nutrients. But what nutrients one should add and in what quantities is a problem the more complex the more kinds of nutrients have to be applied.

FERTILIZER STUDIES ON UGANDA SOILS

By H. L. Manning and G. ap Griffith, Department of Agriculture, Uganda

(*Received for publication on 28th June, 1949*)

Prior to 1946 the question of artificial fertilizers was considered to be relatively unimportant. At that time imported fertilizers were so costly that only exceptionally large increases could be of economic value. Responses to cotton seed and cattle manure had been recorded for a number of food crops and for cotton (Martin, 1940).

During 1946 an extensive rock phosphate deposit was opened near Tororo in Uganda. In addition, the possibility of obtaining cheap nitrogenous fertilizers in the future was outlined in development plans. Together these created a need for information regarding yield responses likely to result from the application of these fertilzers. The necessity for increased production per unit area of cultivable land, and more particularly of land cultivated for a number of years, was an equally important incentive for laying out field trials in 1946.

The primary aim of these departmental trials was to determine the effect of locally available fertilizers or those which ultimately might be produced cheaply in East Africa. Of these, the more important were rock phosphate and soda phosphate. The latter, formerly described as "silicophosphate", is produced in Kenya by calcining Uganda rock phosphate with Magadi soda (a deposit consisting largely of sodium carbonate found at Lake Magadi in Kenya). Additional fertilizers used in these trials included sulphate of ammonia and sulphate of potash. Double superphosphate was not available until the latter part of the period covered by this paper. Data accumulated over three years are now summarized. Since much of the future work will be conducted by the fertilizer team of the East African Agriculture and Forestry Research Organization it is hoped that some of the conclusions and inferences will be of value in formulating policy for the conduct of further trials.

Experimental Designs

Designs given by Yates (1937) provided the basis for many of the trials in the series of experiments begun in March, 1946. Fisher (1935) has shown that the basis for inference may be considerably widened by using factorial experiments involving a large number of treatment combinations. Unfortunately, throughout this period, the field staff has been much below established strength. Therefore, except at the major experiment stations, such experiments involved a larger number of plots than could be conveniently managed. The programme then was arranged to check, with a simpler design at a large number of centres, the inferences derived from the comprehensive factorial experiments conducted at the major experiment stations.

Factorial experiments including 3^3, 3×2^3, 2^5, $3^2 \times 2$ and lattice square arrangements have been used with a number of crops at three of the major experiment stations. Previous trials in this country had been confined to a few treatments with relatively large plot sizes. Small-scale variety testing in lattice square and incomplete block arrangements had also been tried. Guard rows were not considered necessary for these variety trials. Consequently the experimental area was not large. However, with a large number of treatment combinations, large plots and few replications probably result in low precision. Plot sizes were therefore reduced from about 1/30 acre to 1/121 acre or less on experiment stations. Previous experience with some of these factorial designs (Manning, 1942–44) indicated that, for cotton, the reality of differences of the order of 15 to 20 per cent could be demonstrated using plot sizes as small as 1/363 acre. While these experiments were being conducted at the experiment stations simple trials were laid out at a large number of centres in Buganda, and the Eastern, Northern and Western Provinces. The designs for these were simple randomized complete blocks with a small number of treatments. Plot size for these was at first about 1/40 acre. Later experience showed that for grain crops sizes of 1/60 acre were satisfactory. Plot sizes were ultimately reduced to 1/183 for sorghum, 1/145 for cotton and 1/110 acre for root crops.

Various treatment combinations included sulphate of ammonia at 0, 1 and 2 cwt./acre; soda phosphate 0, 1 and 2 cwt./acre; rock phosphate 0, 2½ and 5 cwt./acre; sulphate of potash 0, 1 and 2 cwt./acre; lime 0 and 5 tons/acre; and dung 0 and 2 tons/acre. Later double superphosphate was applied at 0, 1 and 2 cwt./acre, and latterly at rates as high as 4 cwt./acre. Parallel applications of rock phosphate were then 0, 5 and

10 cwt./acre. Applications were either broadcast or localized in drills about three inches from the plants. In the case of soda phosphate and sulphate of ammonia there were some losses due to scorching where localization was too close. The time of application varied with the crop grown and the fertilizer used. In some instances applications were made either at planting or two weeks before: in others the time of application was delayed until six weeks after planting. Such delays are warranted by the late flowering of cotton which has an extended growing season in this climate.

Experiments conducted outside the main experiment stations were usually simple paired randomized blocks with three levels each of nitrogen and phosphate. Localities were then grouped according to approximate soil types and the whole analysed as a serial experiment.

Unless otherwise stated the levels of fertilizer application were for soda phosphate 0, 1 and 2, for sulphate of ammonia 0, 1 and 2, and for rock phosphate 0, 2½ and 5 cwt. per acre.

The experiments are summarized in Tables 1 and 2 (*see* pages 89–90).

Experimental Results

Trials have now been conducted with a number of crops at more than 20 centres in the past three years. A detailed description of these would be tedious. Therefore only the important general conclusions are discussed for individual crops.

Finger millet (*Eleusine coracana*) is the most important grain crop grown in the Protectorate.

Preliminary trials were conducted in 1946 at four centres in the Eastern Province. These indicated that both rock and soda phosphate led to small-yield increments when applied at, or soon after, planting. Yield response to nitrogen was considerably higher. The average effects of phosphates without nitrogen was 13 per cent. Nitrogen and phosphate together gave a yield increase of about 56 per cent. There was evidence that the double dressing of rock phosphate (5 cwt./acre) was as effective as the single level of soda phosphate. Similar trials in the Western Province at four centres gave small and inconclusive increments.

During 1947 there were three series of trials. The first group was at four localities in Teso: the second at four localities in Mbale and Busoga, and the third at only two localities, one of which was the Serere or "short grass" experiment station. The design was paired replicates of the form 3 × 3, with all applications applied at or soon after planting. Differences due to nitrogen were in all cases highly significant, the response to single level over ten localities averaging 25 per cent, and to the double dressing, about 40 per cent. The previous year's inference was thus confirmed. Responses to soda phosphate were small and for the double dressing generally negative. There was no evidence at any of the ten localities of a significant interaction between nitrogen and phosphate. Crops were grown at most of these sites to estimate residual effects. Yield differences of the sorghum indicator crop were no larger than could have occurred by chance.

The 1948 series were also grown at ten localities, and with the substitution of rock for soda phosphate, were of similar design to those of 1947. The rock phosphate was applied in rows before planting, and the nitrogen about two weeks later. Trials at three localities germinated so badly that they were subsequently abandoned. Summarized data from the remaining seven localities indicated that the average response to nitrogen was again of considerable magnitude, though somewhat lower than for the previous season. The single level led to an average increase of 23 per cent. Response to the double dressing was about 33 per cent. The effects due to rock phosphate were small (about 5 per cent for both the single and double dressing). This was the first occasion on which the interaction between nitrogen and phosphate was found to be statistically significant ($p=0.05$). The interaction resulted from a small depressing effect from phosphate either without nitrogen or at the single level, compared to the yield increases due to phosphate on the presence of the double dressing of nitrogen.

A further comprehensive trial with finger millet was laid down during 1948 at the "short grass" experiment station. Comparisons included rock and superphosphate each at three levels, with and without nitrogen, and the phosphate applied broadcast and localized. Average yield increases due to superphosphate were of the order of 8 per cent. Those due to rock phosphate were negligible. There was some evidence that the broadcast method of application was more effective than the localized.

Maize is now grown in the south-easterly part of Buganda and seems likely to become of increasing importance.

Trials were conducted in 1947 with nitrogen and soda phosphate at four sites on land in various years of cultivation following an

TABLE 1

SUMMARY OF FERTILIZER TRIALS WITH GRAIN CROPS, 1946–48

Crop	Locality	Design	Treatments. Cwt./Acre	Fertilizer Placement: Time	Fertilizer Placement: Method	Plot Size	Yield Level	L.S.D.	Results	Remarks
Eleusine (1946)	Kaberamaido Serere .. Kuju .. Katakwi .. Kumi ..	2 x 2 x 2	Sulph. of Ammonia, 0, 2; Rock Phosphate, 2½, 5; Soda Phosphate, 1, 2	Before	Broadcast	acre 1/35 " " " "	2,131 lb. 2,698 lb. 2,478 lb. 3,013 lb. 1,580 lb.		Average P=119%; N+P=145% .. .. Average P=123%; N+P=142% .. .. Average P=116%; N+P=157% .. .. Average P=119%; N+P=204% .. .. Average P= 88%; N+P=135%	Second level of Rock=120%. Single level of Soda=119%. Double Soda Negative.
Serial Analysis							2,380 lb.	8·8%	P=113%; N+P=156%	
Eleusine (1947)	Vukula .. Kibale .. Kisoko .. Budaka ..	3 x 3	Sulph. of Ammonia, 0, 1, 2; Soda Phosphate, 0, 1, 2.	After	Broadcast	1/45 " " "	2,022 lb. 2,349 lb. 3,793 lb. 3,088 lb.	35·8% 16·0% 37·2% 18·8%	1N=125%; 2N=150%; 1P=101%; 2P= 99% 1N=132%; 2N=163%; 1P= 98%; 2P=108% 1N=163%; 2N=131%; 1P= 92%; 2P= 75% 1N= 91%; 2N=129%; 1P=100%; 2P= 84%	Harmful effect of Soda Phosphate reflected in plant stands.
Serial Analysis							2,813 lb.	14·9%	1N=129%; 2N=140%; 1P= 97%; 2P= 88%	
Eleusine (1947)	Kuju .. Katakwj .. Kumi .. Bukedea ..	3 x 3	Sulph. of Ammonia, 0, 1, 2; Soda Phosphate, 0, 1, 2.	After	Broadcast	1/45 " " "	2,652 lb. 1,447 lb. 2,656 lb. 1,960 lb.	15·7% 32·0% 17·0% 26·7%	1N=128%; 2N=143%; 1P= 98%; 2P= 94% 1N=123%; 2N=114%; 1P=121%; 2P=117% 1N=121%; 2N=140%; 1P= 98%; 2P=103% 1N=116%; 2N=169%; 1P=109%; 2P= 88%	
Serial Analysis							2,180 lb.	12·8%	1N=123%; 2N=143%; 1P=104%; 2P= 99%	
Eleusine (1948)	Kaberamaido Serere ..	3 x 3	Sulph. of Ammonia, 0, 1, 2; Soda Phosphate, 0, 1, 2.	After	Broadcast	1/45 "		32·7% 18·8%	1N=129%; 2N=121%; 1P= 97%; 2P=104% 1N=109%; 2N=118%; 1P=122%; 2P=132%	
Eleusine (1948)	Budaka .. Bukedea .. Kisoko .. Bulopa .. Kumi .. Kuju .. Kaberamaido	3 x 3	Sulph. of Ammonia, 0, 1, 2; Rock Phosphate, 0, 2½, 5.	Rock Before Nitrogen After	Localized in Lines	1/62 1/57 1/62 1/58 " " "	2,910 lb. 3,520 lb. 2,470 lb. 2,990 lb. 3,590 lb. 2,510 lb. 3,220 lb.	Serial Analysis	1N=151%; 2N=159%; 1P=106%; 2P=108% 1N=109%; 2N=120%; 1P= 96%; 2P= 99% 1N=155%; 2N=208%; 1P=122%; 2P=114% 1N=118%; 2N=124%; 1P=103%; 2P=110% 1N=115%; 2N=123%; 1P=105%; 2P=101% 1N=141%; 2N=160%; 1P=106%; 2P=114% 1N=104%; 2N= 95%; 1P=103%; 2P= 95%	N P interaction at Kisoko. Locality x N interaction also significant.
Serial Analysis							3,030 lb.		1N=123%; 2N=133%; 1P=105%; 2P=105%	
Eleusine (1948)	Serere ..	Lattice Square	Superphosphate, 1, 2, 3; Rock Phosphate, 2½, 5, 10; Sulph. of Ammonia, 1, 2. Broadcast and Localized.	P Before N After	Broadcast and Localized	1/60·5	4,156 lb.	N.S.	Super—Broadcast, 108%; Localized, 107% .. Rock —Broadcast, 99%; Localized, 98% ..	
Maize .. (1947)	Kakumiro .. Kawanda .. Bukalasa .. Ngogwe ..	3 x 3	Sulph. of Ammonia, 0, 1, 2; Soda Phosphate, 0, 1, 2.	After	Localized	1/45 " " "	3,683 lb. 3,608 lb. 4,280 lb. 3,225 lb.	18·1% 23·0% 21·0% 15·6%	1N=113%; 2N=123%; 1P= 98%; 2P=104% 1N=119%; 2N=131%; 1P=105%; 2P= 96% 1N=117%; 2N=120%; 1P= 98%; 2P= 89% 1N=114%; 2N=121%; 1P=103%; 2P= 96%	
Serial Analysis							3,696 lb.	19·7%	1N=116%; 2N=124%; 1P=101%; 2P= 96%	
Maize .. (1948)	Kawanda .. Bukalasa .. Mukono .. Ngogwe ..	3 x 3	Sulph. of Ammonia, 0, 1, 2; Rock Phosphate, 0, 2½, 5.	P Before N After	Localized	1/58 " " "	2,975 lb. 5,626 lb. 3,294 lb. 5,336 lb.	Serial Analysis	1N= 90%; 2N= 94%; 1P=100%; 2P=101% 1N= 99%; 2N= 92%; 1P=118%; 2P=106% 1N= 99%; 2N= 93%; 1P=100%; 2P=106% 1N=111%; 2N=107%; 1P=107%; 2P=107%	
Serial Analysis							4,303 lb.		1N=101%; 2N= 97%; 1P=108%; 2P=105%	
Sorghum (1947)	Kawanda ..	Lattice Square	Rock Phosph., 1, 2, 3; Soda Phosph., 1, 2, 3; Sulph. of Amm. 0, 2; Time; Method.	Before and After	Localized and Broadcast	1/183	752 lb. (Unthreshed)	N.S.	Average Rock=101%; Average Soda=105% Before=105% After=101% Broadcast - 104% Localized=102% Average Superphosphate=118%	Severe dry season.
(1948)	Kawanda ..	Lattice Square	Super., 1, 2, 3; Rock, 2½, 5, 10; Sulph. of Amm., 0, 2; Method.	P Before N After	Localized and Broadcast	1/80	1,050 lb. (Unthreshed)	N.S.	Average Rock Phosphate=106%	
(1948)	Buwunga ..	2x2x2x2x2	Lime, 0, 5 (Tons); Dung, 0, 2 (Tons), Sulph. of Amm., 0,2; Super., 0,2; Potash, 0,2.	L, Ca, D, Before N, K, After	Localized and Broadcast	1/30	868 lb. (Unthreshed)	28·2%	Superphosphate=132%	Highly leached acid soil.

TABLE 2

SUMMARY OF FERTILIZER TRIALS WITH OTHER CROPS, 1946–48

Crop	Locality	Design	Treatments. Cwt./Acre	Fertilizer Placement		Plot Size	Yield Level	L.S.D.	Results	Remarks
				Time	Method					
Cotton (1946)	Kawanda .. Ngetta .. Serere ..	3 x 3 x 3	Sulph. of Ammonia, 0, 1, 2; Soda Phosphate, 0, 1, 2; Sulph. of Potash, 0, 1, 2.	Before	Localized Broadcast Localized	*Acre* 1/72 ,, ,,	651 lb. 1,381 lb. 854 lb.	12·8% 14·3% 17·6%	1N=105%; 2N= 97%; 1P= 99%; 2P= 91% 1N=105%; 2N=109%; 1P=102%; 2P=101% 1N=105%; 2N=119%; 1P=104%; 2P=113%	Planted in July. Planted in June. Planted in June.
(1946)	Kawanda ..	3 x 2 x 2 x 2	Three Varieties, Sulph. of Amm., Soda Phosphate, Sulph. Pot., all 0, 2.	Six Weeks After	Localized	1/110	862 lb.	19·2%	Varieties highly significant treatment differences negligible	Planted late May.
(1947)	Kawanda ..	3 x 3 x 3	Three Varieties, Sulph. of Amm., 0, 1, 2; Rock Phosphate, 0, 2½, 5.	P Before N After	Localized	1/145	1,270 lb.	9·1%	1N=103%; 2N=102%; 1P=103%; 2P=101% Height response to P highly significant ..	Planted early June.
(1947)	Kawanda ..	3 x 3 x 3 Split-plot	Time of Opening Spacing Sulph. of Ammonia, 0, 1, 2.	After	Localized	smallest 1/60·5	821 lb.	14·0% 4·0%	Spacing highly significant .. .. 1N=105%; 2N=106%	Planted late May.
(1948)	Serere ..	Lattice Square	Superphosph., 1, 2, 3; Rock, 2½, 5, 10; Sulph. Amm., 1, 2; Broadcast and Localized	P Before N After	Broadcast and Localized	1/60·5	879 lb.	N.S.	Rock 1= 95%; Rock 2=103%; Rock 3=105% Super 1=105%; Super 2=112%; Super 3=104% Broadcast=107%; Localized=101%	
Ground-nuts (1947)	Kawanda .. Serere ..	3 x 3 x 2	Sulph. Amm., Soda Phosph. Varieties; Sulph. Amm., Rock Phosph., Varieties.	After	Localized in Lines	1/84	2,600 lb. 2,150 lb.	17·6% 18·8%	1N=103%; 2N=100%; 1P=116%; 2P=101% 1N=116%; 2N=101%; 1P= 98%; 2P= 95%	Variety differences significant.
Sugar Cane (1946-48)	Kakira ..	2 x 2 x 2	Sulph. Amm., 0, 2; Soda Phosph., 0, 2; Sulph. Potash, 0, 2; (Java Variety).	After	Localized	1/16	40·4 tons	30·0%	N=104%; P=113%; K=103%	
Sweet Potatoes (1946)	Kigezi ..	R.C.B.	Soda Phosphate, 0, 1, 2; Rock Phosphate, 0, 2, 4.	Before	Broadcast	—	—	N.S.	Rock 1=110%; Rock 2=118% .. .. .. Soda 1=110%; Soda 2=113%	

elephant grass (*Pennisetum purpureum*) rest. The average response to the single level of nitrogen was 16 per cent and to the double dressing about 24 per cent. Differences due to soda phosphate were small and, as with finger millet, negative for the double dressing. No significant interaction between nitrogen and phosphate was recorded. Since there was no significant interaction between locality and nitrogen in this season it was inferred that the average yield response of maize to nitrogen was of the same relative magnitude whether on land newly opened from elephant grass, or land in the later stages of cultivation.

This inference may require further scrutiny in the light of current studies in connexion with accumulation of soil nitrates.

Trials in 1948 were similar to those of 1947, but rock phosphate was used instead of soda phosphate. Six sites were chosen though only four were used for the serial analysis of variance, the others having missing plots. Only differences due to locality could be considered real. The average effects due to nitrogen were small. This will be discussed later. Response to the single level of phosphate was about 8 per cent.

Sweet potatoes are valuable as a relatively short-term food crop throughout the Protectorate. Simple trials were conducted at one site in 1946 and led to yield increments of the order of 18 per cent for the double dressing of rock phosphate and 13 per cent for the soda phosphate. Experimental error was, however, so high that the reality of these differences could not be demonstrated.

Sugar cane is grown commercially in a restricted area, part of which is of relatively high fertility. An N.P.K. trial was laid down in 1946 using soda phosphate as the source of phosphate. All fertilizers were applied in drills two months after planting. Yields per acre after a growing season of 20 months and with a quick maturing variety were relatively high. Differences between treatments were not statistically significant. The greatest yield increment was due to soda phosphate and amounted to 13 per cent. Responses to nitrogen and potash were negligible.

Groundnuts are an important cash crop in many areas of the Protectorate. Harvest expenses and transport difficulties are, however, important factors in restricting wider acreages. Comprehensive factorial experiments were laid down at the two major experiment stations in 1947. At the centres representing the "elephant grass" areas, nitrogen and soda phosphate were used with two varieties. A similar comparison was made at the centre representing the "short grass" areas, using instead rock phosphate as the source of phosphate. One of the primary aims of these trials was to ascertain whether varieties with markedly different *yield syntheses* responded differently to induced varied fertility levels. At both centres fertilizers were applied in rows close to the plants at the time of flowering, approximately four weeks after planting.

Responses to nitrogen at the "elephant grass" centre were small and inconclusive. Response to the single level of soda phosphate was of the order of 16 per cent, though the response to the double dressing was negative (quadratic $p=0.01$). There were no significant interactions either between nitrogen and phosphate or between treatments and varieties. At the short grass centre the largest response was obtained from the single level of nitrogen, though a negative response was obtained from the second level. Differences due to rock phosphate were small and inconclusive. Again there were no significant interactions either between nitrogen and phosphate or treatments and varieties.

Sorghum is perhaps of chief importance in the manufacture of beer. Experimentally it is valuable as an indicator crop because of the relative ease of reaping and freedom from theft. Trials have now been conducted at the elephant grass experiment stations in 1947 and 1948. Comparisons made in the first year were between soda and rock phosphate each at three levels with and without nitrogen, the phosphates to be applied drilled and broadcast, and to be applied before and after planting. A lattice square design was chosen to accommodate the large number of treatment combinations. The 1947 trial suffered from unseasonably dry weather during growth and maturity, which was thereby considerably delayed. Although no real differences between final yields could be demonstrated, there was evidence that the emergence of plants at the end of six weeks was inhibited by the larger applications of soda phosphate applied in drills before planting.

The trial in 1948 was similar except that superphosphate and rock phosphate were compared. The average response to superphosphate was of the order of 18 per cent. Rock phosphate in the same trial gave a yield response of only 4 per cent. Differences due to nitrogen were negative, and those due to method of

application were negligible. It is worth noting, however, that the broadcast method was slightly better than the localized.

A site with known low-nutrient status, locally termed "lunyu", was chosen for a 2^5 experiment using nitrogen, superphosphate, potash, lime and dung. Only differences due to phosphate and to the interaction of lime and dung proved to be statistically significant. The response to superphosphate was the highest recorded in any experiment, being about 32 per cent. A feature of this trial was the extreme variability of growth—a characteristic of the "lunyu" soils.

Cotton is, of course, the most important cash crop of the Protectorate and in consequence received the greatest attention. It should be emphasized, however, that experiments with cotton present many difficulties. Under rain-grown conditions crop losses due to plant diseases, insect pests and, perhaps of greatest importance, excessive rainfall at maturity, are among the serious sources of experimental error. Again the crop is reaped no less than five times during the season and so is equivalent to five similar experiments with crops requiring but a single harvest.

Three N.P.K. experiments were laid down during 1946, one each at the two major experiment stations and one at the station in the Northern Province. Soda phosphate was used in all these trials. Fertilizers were applied before planting. Yield responses to nitrogen were obtained at the "short grass" (Serere) and the Northern Province (Ngetta) experiment stations (19 and 9 per cent) and for the former site to soda phosphate (13 per cent). At the "elephat grass" centre differences due to fertilizers were small, though a linear negative effect ($p=0.01$) was recorded for the effect of soda phosphate.

A further trial was conducted at the elephant grass centre (Kawanda) with three varieties each at two levels of nitrogen, phosphate and potash. All fertilizers were applied after planting. Yield differences were small for all treatments, though a uniformly negative effect was recorded for nitrogen with this earlier planted cotton.

During 1947 further trials were conducted at the "elephant grass" and "short grass" experiment staitons, two at the former and one at the latter. The trial at the "short grass" centre suffered from loss of stand due to heavy rains immediately after the application of nitrogen, and was therefore abandoned. The first experiment at the "elephant grass" centre (Kawanda) was of the form 3^3 involving three varieties each of three levels of rock phosphate and nitrogen. Rock phosphate was applied in drills close to but not in direct contact with the seed at planting towards the end of May. Nitrogen, similarly placed in drills, was applied about four weeks after planting. Plant emergence counts at 14 days showed that rock phosphate stimulated germination of all varieties. Prior seed treatment of the varieties differed in that one variety was delinted with concentrated sulphuric acid, the remaining varieties being untreated. This early stimulus was reflected in plant height at 98 days, response to rock phosphate being for one untreated variety of the order of 15 per cent. Response of the same variety to nitrogen was only 6 per cent. However, not all of these differences were reflected in yield which was uniformly high (more than 1,200 lb. per acre of seed cotton). The statistical significance of the interaction between varieties and nitrogen will be of interest to plant breeders. Much of this interaction was attributed to the response of the varitey with the largest number of bolls per plant. Yield response to nitrogen of this variety was about 8 per cent: responses of the other varieties were negligible.

Several interesting features of this experiment are worthy of note. The land was in the fourth year of cultivation after an elephant grass ley. Crumb structure would therefore be expected to have deteriorated. In addition, the slope of the land necessitated planting on ridges to reduce soil wash. It is possible that the moisture retention contributed to the unexpectedly high yields obtained in this fourth year of cultivation. Cotton yields recorded from this field for the previous three seasons were respectively 591, 803 and 622 lb. seed cotton per acre. At least one of these seasons was considered to be satisfactory for growth and yield of cotton.

The second experiment at Kawanda, a split plot design of the form 3^3, was also conducted during 1947. Treatments were time of preparation after opening from elephant grass in February: spacing and added nitrogen. Land had been under elephant grass for three years. One of the primary objects of this experiment was to determine the optimum time, within limits May to June, to plant cotton following opening from elephant grass. Griffith (1949) has shown that accumulation of nitrate nitrogen proceeds very slowly in the presence of the large amounts of organic resi-

dues associated with clearing from elephant grass. Consequently added artificial nitrogen was also an important treatment. Yield responses to the different times of opening did not differ statistically. Responses due to nitrogen were, however, statistically significant though not of great magnitude (about 8 per cent).

During 1948 a further trial was conducted at Serere. Comparisons included three levels each of superphosphate and rock phosphate, both broadcast and localized. Average yield responses due to superphosphate were about 7 per cent and to rock about 1 per cent. Again the broadcast application was more effective than the localized method.

Germination Tests

Trials reported in the previous sections indicated that some part of the depressing effect of soda phosphate may have been due to its harmful effect on germination. Consequently various germination trials were conducted with cotton seed. The first was laid out in July, 1947, using acid treated (concentrated sulphuric acid) and untreated seed. Treatments included ammonia and sulphate of ammonia. There was a marked depressing effect on germination resulting from soda phosphate placed close to but not in direct contact with the seed. A similar effect was recorded for sulphate of ammonia placed in the same manner. This effect, of course, is well known. An unexpected and highly significant increase was recorded for the germination of both acid treated and untreated seed with rock phosphate. An increase was also recorded for both types of seed previously soaked for two hours in dilute ammonia (N/50) and subsequently dried.

Some of the conditions of the above experiment were repeated in a field trial in October, 1947. Rainfall during the two weeks following germination was only 0.31 in. All but the highest applications of rock phosphate (5 cwt./acre) stimulated germination. Again seed soaked in various dilutions of ammonia (N/30, N/40, N/50) stimulated germination, Soda phosphate and a mixture of rock phosphate with sodium carbonate led to reduced germination. Sulphate of ammonia, sulphate of potash and Magadi soda all depressed germination to an extent comparable with that recorded for the highest application rates of soda phosphate.

Greenhouse and Outside Pot Experiments

During the past two years any outstanding responses from field trials have been followed up with small pot experiments. This is, of course, a reversal of the usual procedure. Our main reason for this is the fact that primary indications such as plant height and perhaps early gross weight of plants are not always in fact reflected in final yields. This is illustrated by plant height responses as late as 98 days after planting.

A relatively large yield response to superphosphate of sorghum grown on "lunyu" soil was followed up in a greenhouse trial with similar soil from four localities. Treatments were three levels each of nitrogen, superphosphate, potash and lime. Response of early plant height to the single level of superphosphate was 8 per cent. Response to the large dressing was 26 per cent. This response is, of course, similar to that obtained in the field trial. Potash led to a response of 12 per cent. Since nitrate accumulation has been shown to be appreciable under bare soil conditions, it is possible that the independent effect of added artificial nitrogen was obscured. In spite of this the response to the larger application was 7 per cent.

A pot experiment with sorghum on soil from land in its fourth year of cultivation had for treatments three levels of nitrogen (0, 2 and 4 cwt./acre), three levels of superphosphate (0, 2 and 4 cwt./acre), potash, lime, and time of application. Yield responses were small for all treatment combinations. However, the average yield response to lime was 7 per cent. Response to the highest level of superphosphate was only three per cent.

The stimulation effect on early growth resulting from rock phosphate, though not always reflected in yield, has now been repeated on three occasions, under greenhouse as well as under field conditions.

Discussion

Fertilizer trials have been conducted in Uganda for the past three years. Modern experimental designs have been used for most of these trials and the results may therefore be statistically analysed. Various forms of artificial fertilizers have been tried during the period. The more important were sulphate of ammonia, sulphate of potash, and three forms of phosphate: rock, super and soda phosphate.

Fertilizer combinations also included lime (as air-slaked) and dung. This latter is usually fully exposed to the weather and exhibits considerable variability both in composition and its effects on various crops.

Yield responses have been reported for a number of crops. These crops included finger millet, maize, sweet potatoes, sugar cane, groundnuts, sorghum and cotton. Of all fertilizers tried only nitrogen led to appreciable yield increases. Indeed, it is abundantly clear that the mere application of artificial fertilizers does not provide a substitute for inefficient cultural practices. For example, Manning (1949) has shown that a very considerable increase of cotton production may result from sowings near an optimum sowing date. Yields per acre from experiment stations often exceed 1,000 lb. By contrast yields from smallholdings on the same areas are estimated to be about 500 lb. per acre. Again, where rainfall is marginal, the moisture conservation which would result from efficient methods of ridge cultivation might have far-reaching importance. The relatively small yield increments so far shown to result from the use of artificial fertilizers can, therefore, have no real significance until existing systems of native agriculture adopt the major improvements demonstrated on the experiment stations.

For convenience the conclusions from the trials are summarized under the heading of the three important plant foods: nitrogen, phosphate and potash. The effects of lime are obscure on soils of low pH and so far it can only be stated that no large responses have been obtained.

NITROGEN

(a) Yield Responses.

Nitrogen has been shown to provide the greatest single stimulus to plant growth and yield. Average yield responses for grain crops have, with one major exception, been practically linear: finger millet, grown over three seasons and at a total of 22 localities in the Eastern Province has given responses of about 25 per cent to 1 cwt. of sulphate of ammonia and about 40 per cent to 2 cwt. Maize has been grown for two seasons and yield responses from the first season at four localities were 16 and 24 per cent respectively from 1 and 2 cwt. of sulphate of ammonia. Yield responses during the second season at seven localities were negligible from both levels. A possible explanation of this failure to respond is later discussed under the heading of accumulated nitrate nitrogen. Yield responses of other crops were inconclusive.

During the first season with maize it was shown that there was no material difference between the relative magnitude of the nitrogen response with land in various years of cultivation after rest. That is responses on land newly opened from elephant grass though higher were of the same order as those from land in the third and fourth years of cultivation. In the light of current work on nitrate accumulations these conclusions may require some qualification.

(b) Accumulation of Soil Nitrogen.

During the course of the fertilizer studies parallel investigations have been conducted in connexion with soil nitrate. Evidence has been adduced by Griffith and Manning (1949) to show that substantial quantities of nitrate were accumulated at the elephant grass station (Kawanda) during favourable conditions over the 1948 season. Assuming that the top 6 in. of an acre of land amount to 1,000,000 lb., then the highest weekly analysis for the same station suggests that about 500 lb. per acre of nitrate may be accumulated. This is roughly equivalent to 500 lb. per acre of sulphate of ammonia. There is no information yet available concerning the accumulations on the short-grass areas.

Hardy (1946) has shown under certain conditions in the British West Indies that accumulation of nitrate nitrogen in the soil may greatly influence growth and yield of cotton. Provisional limits of adequacy were given in the same paper. According to his estimates the limit of adequacy for cotton may be attained for a large part of the growing season in Uganda. This may provide a possible explanation of the inconclusive responses which have been obtained from nitrogenous fertilizing of cotton and, during the 1948 season, of maize. In this connexion it should be noted that the peak of cotton flowering occurs about 90 days after planting. Since the uptake of nitrogen is probably greatest at this time it is possible also that applications after ten weeks might lead to yield responses not so far demonstrated. Clearly, with the protracted growing season for most tropical crops at altitudes of four thousand feet, further investigations are necessary in connexion with time and method of application of nitrogenous fertilizers.

(c) Conclusions.

There is sufficient evidence to show that nitrogenous fertilizing without parallel studies of the amount of accumulated nitrogen and the mechanism of its origin would be of limited

practical value. The fact that a peak of these accumulations coincided with the likely onset of flowering of June-planted cotton may be of far-reaching importance in improving average yields per acre. Should this accumulation be recorded over areas outside of the elephant grass regions its importance would be further enhanced.

Prevailing prices of grain crops also minimize the value of added nitrogenous fertilizers. Thus the 25 per cent yield increases correspond to an average increment of about 600 lb. of head and grain of eleusine. An additional increase of 300 lb. may be expected with 2 cwt. per acre of sulphate of ammonia. The values of these increments are respectively Sh. 35 and Sh. 55. Correspondingly low values may be expected with maize where the nitrate status is low. Evidently the equivalent price of sulphate of ammonia per ton would have to be less than £30 to make an application worth while for eleusine.

PHOSPHATE

(a) *Yield Responses.*

Yield increments obtained from Uganda rock phosphate and the calcined product (soda phosphate) have generally been small (10 to 15 per cent). Indeed, negative responses have been recorded for the soda phosphate. Some part of this may be ascribed to a harmful effect on germination. More recent samples may prove to be less harmful. The most favourable response to phosphate—as double superphosphate—has been about 30 per cent on a soil of known low-nutrient value. However, over a range of soils of average fertility responses to superphosphate have also been small (7 to 18 per cent).

(b) *Effect on Germination.*

During the early stages of the investigations it was apparent that the then available forms of soda phosphate were harmful to early growth. Later experiments, when the fertilizers were applied after planting, showed that this effect was less pronounced. Also it was shown that responses were obtained from applications after planting. This was demonstrated with groundnuts, where the application was made 30 days after planting with a crop whose normal cropping period was about 130 days.

By contrast a stimulating effect of Uganda rock phosphate was recorded both in greenhouse and field experiments. According to accepted tests for availability of phosphate, Uganda rock phosphate is of low solubility. Yield responses though small have, however, been obtained, so that the reason for the stimulating effect is not clear. Possibly this may be due to a physical moisture relationship or merely chemical stimulus. In many instances the stimulation to early growth has not been reflected in yield. This serves to emphasize the need for full-scale field trials, since these early indications, sustained up to 100 days, would otherwise be misleading. A negative trend of the highest application rates of all forms of phosphate is now receiving attention.

(c) *Placement.*

Indications from method of placement have not been conclusive. There is, however, a consistent trend in favour of the broadcast method. The question of phosphate response may be connected with phosphate fixation; that is the effective surface area of the particles with the broadcast applications might conceivably be greater than that with the locally immobilized and often larger applications. At the same time if toxic elements are present the dispersal is greater with the broadcast method. Further experiments are therefore being conducted not only in regard to position, but also with fractional applications at various intervals.

(d) *Interaction between Nitrogen and Phosphate.*

Suggestions based on inadequate evidence have been put forward that an interaction between nitrogen and phosphate might be expected. Such interactions have not, in fact, been generally recorded. It is unfortunate that estimates of soil nitrogen were not possible for the few experiments where statistically significant interactions were recorded. However, this important aspect is still receiving attention. Evidently nitrate accumulation in the amounts previously mentioned could easily obscure such an effect, which must therefore be studied in parallel with the accumulation of nitrate nitrogen.

(e) *Conclusions.*

Clearly no spectacular increases may be expected from applications of rock or soda phosphate. Even superphosphate has led to only small responses except on impoverished soils. Possibly fractional applications of rock or superphosphate may lead to larger responses. Further the continuous broadcast application of rock phosphate—by far the cheapest source of phosphate in East Africa—may lead eventually to satisfactory yield increases. This has been demonstrated in South Africa where Hall and Meredith (1946) have shown that continuous applications of Langebaan rock phos-

phate are considerably better than calcined phosphate. However, both were inferior to standard superphosphate.

Potash

(a) Yield Response.

Applications of sulphate of potash have given uniformly poor responses. Experiments with cotton on the three major experiment stations, and one with sugar cane, indicate that there is no obvious potash deficiency.

(b) Conclusions.

The potash status of Uganda soils is not low compared with other countries (Griffith, 1938). No large response could therefore be expected. In addition, as Hardy (1946) suggests, potash requirements are likely to be highest under conditions of intense solar radiation. Since cotton and, of course, other crops grown at this altitude (4,000 ft.) are usually cultivated when daily hours of sunshine are reduced, it may be inferred that potash requirements would also be low. Again, it has been demonstrated by Ripperton *et al.* (1944) that elephant grass (*Pennisetum purpureum*) may take up as much as 1,200 lb. K_2O per acre. Therefore where cotton or, indeed, other crops are planted on land newly opened from elephant grass, and where the bulk of this residue remains on the land, it may be that potash gradually released is adequate to supply the reduced crops requirements. Where the cultivation is likely to extend beyond the three years recommended by the Department of Agriculture, potash might possibly become of greater relative importance than indicated by data so far accumulated.

Summary

Experiments conducted over several years and with various crops have shown that primary expectations of large yield responses to fertilizers have not been fulfilled. More detailed and necessarily slower work, which must now follow, may lead to larger yield responses. Foremost among the new series of experiments are the investigations regarding the source, duration and magnitude of accumulated nitrate nitrogen.

Various interactions, some of which have been demonstrated, may prove to be of great importance. Thus the interaction between variety and fertilizers indicates that prior information on the components of yield is essential in predicting possible yield responses to fertilizers. This is more apparent with crops such as cotton. Varieties which depend on a large number of bolls rather than boll size for cropping capacity necessarily have a large plant structure. Response to nitrogenous fertilizers would therefore be expected to be appreciable. Possible interactions between nitrogen and phosphate cannot be investigated until accumulation of nitrate nitrogen is more fully understood. If the limits of adequacy are satisfied by these accumulations it is obvious that added nitrogen could have little effect. Alternatively, with excessive rainfall and a leaching of these accumulations, added nitrogen might indicate a nitrogen and potash interaction which would, of course, be obscured in the previous hypothesis.

Where the application of fertilizers under certain conditions can be positively harmful, the unrestricted distribution of these to farmers with no previous handling experience could condemn their actual value for a long time. Thus the form of soda phosphate used, sulphate of ammonia, nitrate of soda and sulphate of potash are all known to damage seedlings if applied too close. Any small gains would therefore be offset by the loss of plant stand. The grower is interested only in gross returns per unit area of land, and the subsequent disillusionment would be probably be permanent.

The negligible responses to fertilizers on most soils in Buganda suggests that the soil fertility following an "elephant grass" ley is sufficient for most crops. This does not apply to the Eastern Province which employs various short grasses on soil of inherently lower fertility status. Land pressure in the urban areas such as Kampala indicates that cultivation either persists or will in the future be necessary on land beyond the third year of cultivation. There is some evidence that responses might be larger on such land. Indeed, this would be expected to be axiomatic. Therefore further comprehensive trials on land in the fourth and fifth years of cultivation should be conducted in future programmes.

An impression of general uncertainty evidently prevails after three years of experiments. It has been our deliberate aim to stress this aspect. Routine experiments have clearly shown that no spectacular yield responses are likely to be obtained except on soils of known low-nutrient status. Stress must now be laid on the necessity for patient and detailed work along lines which these trials have indicated. Fundamental problems such as nitrate accumulation,

phosphate fixation under these conditions, and potash requirements under various intensities of solar radiation must be solved. Even where these are solved, the question of time and method of applying proven fertilizers present important problems. These recommendations applied later when improved cultural practices and other major improvements have been achieved would no doubt become of real value to the territory.

ACKNOWLEDGMENTS

The numerous trials outside of the experiment stations were conducted by the agricultural officers in the various districts. But for their interest and willingness to take on this extra work the summary of these data would not, of course, have been possible. We have pleasure in acknowledging their valuable co-operation. These remarks apply also to the necessity for the detailed supervision inevitably connected with the comprehensive factorial experiments which were conducted.

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REVIEW

AGRICULTURAL EXTENSION AND ADVISORY WORK (with special reference to the Colonies), by C. W. Lynn.—*Colonial No. 241, published by H.M. Stationery Office,* 1949, *price Sh.* 2, *pp.* 104.

This is a report based on a study made in 1947 of extension and advisory work in England, Canada, the U.S.A., and Puerto Rico, against a background of eighteen years experience as an agricultural officer in the Northern Territories of the Gold Coast, with brief visits to Nigeria in 1936, and to Kenya and Uganda in 1947.

In the Foreword, Sir Frank Stockdale, Deputy Chairman of the Colonial Development Corporation, points out that the Colonial Agricultural Services are now entering a third stage in their development. Most of the Colonial Departments of Agriculture were established about fifty years ago, their main function being the introduction and testing of plants and crops of economic value from other areas, and the study of the indigenous pests and diseases and those affecting the new introductions. In the second phase, which started after the first world war, investigation stations were created for the study of soil problems and of indigenous farming systems as well as continued studies of introduced crops and their pests and diseases. In the third phase, which is beginning now, research work is being intensified and concentrated in regional organizations rather than as sections of Departments of Agriculture, and it will be the duty of the Agricultural Officers of the future to test the application of the results of centralized research in local investigational stations, and to concentrate more and more on "extension" or advisory and educational work.

In view of these changes which are gradually taking place in the work of the Colonial Departments of Agriculture, it is timely to study the methods and results of extension work in other countries, and this report will provide much material for thought and study by agricultural officers. While extension methods which are working well in Canada and the U.S.A. might be adapted to some of the more advanced Colonies, it is probable that new methods of even simpler demonstation and explanation will be required in the backward territories. But the key to the problem lies in the author's words: "Extension presupposes knowledge to extend". Until we can find and prove methods which are obviously superior to the existing native practices we cannot expect progress in extension work, and therefore the technological investigations which link basic research with extension work are of the utmost importance in providing sound material for the extension officer.

D.W.D.

MANGOES ON THE EAST AFRICAN COAST

By W. R. Sethi, Assistant Agricultural Officer, Department of Agriculture, Kenya

(*Received for publication on 14th August, 1949*)

It would be difficult to say just when the mango was first introduced into East Africa. There are large numbers of enormous trees of unknown age all the way along the coast from Lamu to Mokowe, Mpeketoni, Witu, Kipini and from Malindi and its hinterland, all the way to Mombasa and beyond. Little doubt can exist that the earliest cultivation of this tree as a food crop dates back to the days of the old Arab settlers with their slave labour—perhaps back so far as the time when ancient Gede, and other settlements of similar age that are dotted along the coast, were enjoying their glory.

The following are the main varieties to be found on the East African, and in particular the Kenya coast, to-day:—

Superior Varieties

Ngowe.—This variety is very famous in Lamu Island; the fruit is of great size, beautifully rosy-tinted and of well-known popularity on the Mombasa and Nairobi markets. It is usually valued in Mombasa at from 60 cts. to 75 cts. each; in Nairobi at about Sh. 1; while in Lamu it may be obtained for some 25 cts. each. There are a few trees in Malindi and Mombasa which have been planted within the past ten years.

The origin is Goa (whence the name is derived) and it is also found in India.

Boribo.—This variety is smaller, yellow skinned and is famous for its sweetness and freedom from fibre. It is well known in Malindi and takes from four to five years to bear in good soil if well looked after, and its market value in Mombasa is from 30 cts. to 50 cts. each according to season and demand.

Batawi.—This is a recent importation, is popular for its sweetness, is dark red in colour with plenty of flesh and but small seeds. It is a good keeper and is very suitable for distant transport. There is one tree only in Malindi district but there are many on Lamu Island.

Inferior Varieties

Dodo.—This variety is a little larger and rounder than the *Boribo*. It has a greenish yellow skin and is of very excellent flavour but the texture of its flesh is somewhat fibrous.

Zahfrani.—This is the best variety amongst the smaller mangoes, having red flesh and yellow skin when ripe. It is very juicy and is used largely for juice extraction.

Kitovu.—This is the second best in the smaller varieties and is well known for its sweetness. It is also used for juice extraction when the *Zahfrani* are not available.

Punda.—This kind is very common and it is thought that its propagation is due largely to the heedless casting aside of stones by travellers and no doubt to some extent by baboons. The trees are considered communal property, the fruit can be taken freely and it is a popular food in days of famine. This variety is also eaten in the unripe state when it is cooked with maize meal and is the kind usually selected for the manufacture of chutney and pickles in the more advanced countries.

Propagation

The following propagation methods are suggested for improving and increasing the quantity of the superior varieties:—

Seed Propagation.—A seedbed of good tilth and free from any obstruction in the path of the developing shoot of the seedling is very necessary to avoid crooked stems which might render it unsuitable as root stock. Distorted roots, caused by the presence of hard material such as stones in the soil are also undesirable as plants with such defective roots transplant poorly and suffer damage in the course of lifting from seedbed to pots. It has been found that the shelling of stones prior to planting is helpful in eliminating diseased and worm-infested kernels and aids the development of straight taproot and stem, and undoubtedly hastens germination. The shelling operations must be performed very carefully so as to avoid damage. Grading of stones according to size of fruit is not necessary but a stone of very light weight should be discarded. The bigger size of stone is not necessarily of higher germination quality. The planting of the stone with the plumule uppermost has been found to produce a straighter taproot and stem than by planting the stone flat or in any other position. The selection of seed-parents is of the utmost importance and results have shown that inherent vigour is a factor which must never be overlooked. It is a widespread belief that mango seedlings at the nursery stage

do not lend themselves to lifting with naked root. This is not so, and root exposure at the time of transplanting is unlikely to have harmful effects provided the operation is performed on a cool and humid evening when growth is least active. Three varieties of mangoes, *Boribo*, *Dodo* and *Kitovu* tried at Gede settlement have been found to be polyembryonic and have produced a maximum of five seedlings per seed.

Inarching.—The system is not tried here but in India it is commonly done on ten to sixteen months old seedling root-stock. It is hoped that the *Dodo* variety, which is a strong grower, will prove a suitable root-stock for inarching with *Boribo* or *Ngowe*, the best table varieties on the coast. The process needs constant supervision and it is preferable that the operation should be performed as near as possible to the supervisor's station. A period of from three to four months is required for inarching, after which the young tree can be set in its permanent place—provided that the season for planting is suitable.

Budding.—The most successful method of budding tried in India and one which gave so high as 62 per cent takes, is the following:—

A transverse incision is made in the bark of the seedling root-stock of about twelve months age (after the long rains) as far in as the cambium. The bark is then peeled down to a length of $1\frac{1}{2}$ in. after making two vertical, parallel cuts connecting the two ends of the traverse cut. The peeling has to be done carefully so that it may come in one strip. The bud shield is removed, in the same way as for oranges, from the planted shoot, with a small piece of wood attached to it, and this is pushed under the flap until all the exposed edges of the stock rind and bud shield are in perfect contact. This is only possible when the size of the bud stick is the same as that of the stock stem. The flap is turned into position to make it cover the bud shield completely. The covered bud is then wrapped around with paraffined cloth and finally with a piece of dried banana sheath.

Inarching of the mango is a practice that has gained such a strong hold in India that other methods of propagation do not much appeal to the growers. Next to inarching, budding has been found to be a useful method, particularly when the operation is to be performed in the permanent planting place. The above-mentioned propagation methods would be of special value in improving yielding capacity, the quality of the fruit and in reducing the time which the tree takes to reach maturity. The matters most worthy of consideration are the proper varieties for stock and scion, time for the operation and care in handling the operation.

The present note has been compiled from experience gained during fifteen years service on the Kenya coast and past knowledge acquired in school in India and from visits to Indian nurseries from time to time during overseas leave, and from discussions with co-workers in India, to all of whom grateful thanks are due.

REVIEW

BRITISH FARM MECHANIZATION.—*Published every month by the proprietors and printers, Temple Press, Ltd., Bowling Green Lane, London, E.C.1, price 2s. 0d. per copy or 26s. 6d. per annum, postage included.*

This new monthly journal is certain to interest East African farmers who wish to follow progress in farm mechanization. Although most of the implements described have been designed primarily for use in the United Kingdom, some of these should find useful application under East African conditions. In the second number, published in May, 1949, an article by John W. Y. Higgs, entitled "African Development" will be of particular interest, since it discusses the transition from hoe to tractor. Manure handling by machinery is also described, and this might make possible the economical use of cattle manure and compost. Hedge-cutting machinery might find application in clearing fields which have been rested under elephant grass, and the land-clearing machines—giant rakes and powerful root-cutters—include equipment specially built for the Groundnut Scheme. Fodder-cutters, seed drills, crop dusters, potato-planting machinery, draining ploughs, mowers, and small rotary cultivators are also described.

D.W.D.

THE USE OF GROWTH SUBSTANCES IN HORTICULTURE

It was in 1939 that H. L. Pearse first reviewed and outlined the available data on this subject(1). Now, nine years later, the same author has again summarized the very scattered literature on growth substances(2). A scanning of the full table of contents of this more recent review gives an indication of the many and varied practical applications which have resulted from research on synthetic growth substances since the earlier publication. As stated by Dr. Pearse in his introduction "The discovery of the hormone system in plants, culminating in the isolation and later the synthetic production of numerous substances which regulate the growth of plants, has been one of the outstanding achievements of modern plant science. To-day, these substances have found many and varied uses in the commercial culture of plants, and are helping the grower to exercise more and more control over his plant material. New ways in which they can be used to advantage by the practical horticulturist still continue to come to light . . ."

It is inevitable that most of the fundamental research on these substances should have been carried out in temperate climates, but a study of the comprehensive index of typical results obtained by treating cuttings of various species, reveals the names of many plants familiar to horticulturists in East Africa. Amateur gardeners, planters, fruit growers, market gardeners and professional nurserymen will all find much to interest them in this publication. The possibilities to be conjured up are enormous though their practical application or adaptation to many of our East African horticultural crops still remains to be tested.

Pride of place has been given to the use of growth substances in vegetative propagation, and especially the treatment of cuttings whereby rooting is accelerated and more roots per cutting are produced. This was the first practical use to which synthetic growth substances were applied, but at one time there was a tendency for some extravagant claims to be made on their behalf; when these claims were not upheld, they tended to fall into disrepute. As Pearse is careful to point out "it cannot be too strongly emphasized that this treatment should be regarded as a supplement, rather than as in any way a replacement, of the methods normally used by the propagator. . . . . The art of propagation has been built up over centuries of painstaking work and study, and many important details of technique worked out for the propagation of different species". Provided that these details are closely adhered to, growth substances are generally effective when applied to cuttings of plants which are normally easy or only moderately difficult to root. When the propagator becomes careless, or when a full technique has not yet been worked out, disappointments are likely to arise. This has probably been the case with a number of tropical plantation crops, for which the possibilities of vegetative propagation have been intensively explored, especially over the past two decades. In East Africa, coffee is a good case in point. It might be classed as moderately difficult to root from cuttings, since it requires specialized knowledge of the material to select, the preparation of the cuttings, the rooting medium to use, and environment conditions during and immediately after the rooting period. Until these factors are thoroughly understood it is useless to expect much advantage from the application of growth substances. Similarly, amateur gardeners have been disappointed in results obtained by treating cuttings of moderately difficult plants such as *Bougainvillea* spp. or *Petrea* spp. largely because they have not mastered the technique necessary for the successful propagation of these species without treatment. Cuttings from species normally very difficult to root have seldom benefited from treatment. Many of the most valuable horticultural plants fall into this category, and "the development of effective techniques for such plants remains an ideal of propagation research". In East Africa, the Clove and the Tung Oil tree are two important examples of this group; the hardwood cuttings of some deciduous fruit trees, and probably also of some tropical fruit trees and spices, etc., on the propagation of which little work has been done, may also be included here.

After discussing the different methods of treating cuttings and the choice of substances to use, Pearse includes a chapter on the mechanism of induced root-formation. He postulates evidence for the existence of specific internal factors controlling root-formation, and then goes on to recount the results of an experiment with a red and a white variety of *Hibiscus*. From this it was deduced that the white variety was difficult to root because it was naturally deficient in growth substance, and also deficient in another factor which normally came from the leaves. This elucidation of the factors responsible for poor rooting in white *hibiscus*

cuttings is very encouraging, and renews the hope that the factors responsible for poor rooting in other material will eventually be discovered, though they may not be identical for all species.

In the case of the red *hibiscus*, it was "concluded that the main function of the leaves, in the process of root initiation, is to supply the cuttings with sugars and nitrogenous substances".

Other uses of growth substances are then discussed. Results from the treatment of seeds, seedlings, growing plants, and for use in transplanting have been very variable and sometimes conflicting. The inducement of parthenocarpic development in fruits, however, now promises to become a practice of considerable economic importance, though this is a complete reversal of the opinion held in 1939. The tomato has received more attention in this line than other fruits, the object being to use growth substance treatments as an aid to fruit-setting, as well as the production of seedless fruits.

Improved setting of unpollinated flowers has also been achieved with strawberries; larger fruits were obtained, with little seed development. When snap beans were grown under conditions of unfavourable high temperatures, some increase in yield was obtained by treatment, but since the main effect of the treatment is the stimulation of the development of the pod tissues, it cannot be recommended as an aid to the pea and seed bean producers of the Northern Province of Tanganyika, whose objective is seed yield and not pod yield.

It was the knowledge that overdoses of growth substances could cause injury and even death of plant tissues, which led to their trial and development as selective weed killers. The two substances which have been most widely used as herbicides have been most effective against broad-leaved weeds growing among cereal crops, lawns, pastures and other monocotyledonous plants. Not all dicotyledons are controlled, any more than all monocotyledons are resistant, but this division does serve as a general guide.

There is hope that other substances may prove to be effective against grasses, while not harming certain broad-leaved plants. If grasses such as couch, which is such a pest in many plantations and orchards throughout East Africa, could be eradicated by this means, it would be a great boon to many planters and growers.

When used as weed killers it appears that growth substances bring about growth responses, in susceptible growing plants, which are characterized by much distorted stem and leaf growth and inhibition of bud growth, especially the terminal ones, followed later by disintegration of the cells and tissues and ultimate death of the plant. It is noted that "young plants are usually more readily killed than older plants and the effectiveness of the sprays depends to a considerable degree on the temperature and growth conditions when applications were made".

Various weed plants are grouped into three groups according to their sensitivity to these substances. Among those species readily killed may be noted the following which occur in East Africa:—*Amaranthus* spp. (pigweeds); *Chenopodium album* (fat hen); *Dichondra repens*—a most persistent weed, especially of East African lawns; *Erigeron linifolius* (flax-leaved fleabane)—a tap-rooted weed appearing during the dry weather in many parts; *Galinsoga* sp. (McDonaldii); *Portulaca oleracea* (purslane)—also mentioned as being relatively resistant; *Sonchus* spp. (sowthistles). Those relatively resistant include:—*Cyperus rotundus* (Nutgrass); *Hypericum* sp. (St. John's wort); *Lactuca pulchella* (blue lettuce); and *Rumex* spp. (docks); while those very resistant, apart from grasses, include:—*Asclepias* spp. (milkweeds); *Datura stramonium* (common thorn-apple); *Galium aparine* (goose grass or cleavers); and *Oxalis corniculata* (yellow wood sorrel).

More complete lists showing the sensitivity of East African weeds (not quoted in this publication) have appeared and will, no doubt, continue to appear locally, as trials are extended. The sensitivity of plantation and general crop plants must also be gauged. It is to be hoped, however, that the chemical control of weeds, which is expensive at present, will not be allowed to supersede regular farming cropping systems which fundamentally aim at keeping the land clean.

Horticulturists are generally aware that by pinching out a terminal bud, lateral buds can be induced to grow out. Evidence has been produced that there exists in such terminal buds a special inhibiting substance which prevents the growth of the lateral buds below it, until the terminal bud itself is removed. Under certain conditions, synthetic growth substances can replace this action of the terminal bud. Practical advantage has been taken of this by inhibiting sprout development in potato tubers in

storage. Onions similarly treated, however, showed a tendency to rot.

Attempts to retard the opening of buds of deciduous fruit trees and Tung Oil trees have not, as yet, been found practicable, though there are possibilities in delaying shoot development of nursery trees in storage or in transit.

An outstanding exception to the general failure to control flowering, is the case of the pineapple. This is of considerable interest to East African growers. By simply pouring 50 c.c. of growth substance solution of appropriate concentration into the centre of the plant, flowering was controlled. By adjusting the size of the plant and time of treatment, both weight of fruit and time of production could be controlled throughout the year.

Attempts to prolong the life of cut flowers by using growth substances have not been successful so far, but their use in preventing abscission of plant parts has led to one of their most useful aspects in temperate climes, namely the control of pre-harvest drop of fruit, such as apples and pears. This subject is not dealt with by Pearse, as it has been fully reviewed only recently by Vyvyan(3). Other practical uses of this ability to delay abscission, include the prevention of defoliation in cut branches of holly and a few other evergreens, and reducing the bud and flower drop of certain flowers. The possibilities of overcoming leaf and fruit drop in citrus, caused by oil emulsion sprays, have not been finalized. At the other extreme, it is noted that ethylene gas, which is well known as a defoliating agent, has been used to facilitate the harvesting of flowers of essential oils, such as ylang-ylang and chinabox or orange-jasmine.

Other possible uses include the treatment of fruit in store, and for blossom thinning of fruit trees, including the control of the biennial bearing habit.

This brief review outlines the many practical uses to which growth substances have been put, but no attempt has been made to enumerate the various substances involved or their strengths and rates of application. The reader is referred to the publication itself, and thence to the particular references in the comprehensive bibliography, for detailed information. With the growing awaredness of the importance of horticulture locally and the realization that tropical and sub-tropical plantation crops are essentially horticultural, it is to be hoped that the opportunity will not be lost of applying or adapting some of these practices to more of our East African plants and crops. The author's specific warning regarding the treatment of cuttings, that "treatment should be regarded as a supplement, rather than as in any way a replacement, of the methods normally used" bears repetition, however, and might well be used to cover the whole range of the practical uses of growth substances in horticulture.

L. M. FERNIE.

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TWO SPECIES OF STAR GRASS IN KENYA

(*Received for publication on 7th July, 1949*)

By A. V. Bogdan, Pasture Research Officer, Department of Agriculture, Kenya

Star grass is widely distributed and is of great value for grazing in Kenya. It, therefore, naturally arouses considerable interest amongst farmers and agriculturists and is frequently mentioned in the local literature. There are two species of Star grass growing naturally in Kenya: *Cynodon dactylon* Pers. and *Cynodon plectostachyum* Pilger. Following the work of A. S. Thomas in Uganda it has been assumed in East Africa that these two species are extremely difficult to distinguish, that they easily give intermediate, hybrid forms, and that, in general, the tall forms of Star grass belong to *Cynodon plectostachyum,* while the smaller forms belong to *Cynodon dactylon.* A. S. Thomas in "Agriculture in Uganda", 1940, states that "*Cynodon dactylon* and *Cynodon plectostachyum* are hardly distinguishable except in size, and many forms of both exist here". These two species have, however, distinct and easily recognizable differences. The intermediate forms are rare and the height of the grass does not mean much in distinguishing the species. Though it is true that *Cynodon plectostachyum* is usually tall and

TWO SPECIES OF STAR GRASS IN KENYA

1. Flowering head of *Cynodon plectostachyum*.
2. Flowering head of *C. dactylon* (typical)
3. Flowering head of *C. dactylon* (exceptionally vigorous specimen).
4. Stolon of *C. plectostachyum* (on bare ground in dry weather).
5. Stolon of *C. dactylon* (on bare ground in dry weather).
6. Spikelet of *C. plectostachyum*.
7. Spikelet of *C. dactylon*.

(LG = lower glume, UG = upper glume, V = valve, VL = valvule.)

(Heads and stolons half natural size, spikelets x 8.)

robust, *Cynodon dactylon*, being a very variable species, has also tall and robust forms. Pilger, who gave the present name to *Cynodon plectostachyum*, writes (in Engler's Botanische Jahrbücher, Vol. 40, 1908, p. 82) that *Cynodon plectostachyum* is well distinguished from *Cynodon dactylon*: its stems are stout and richly branched, the leaves are covered with spreading stiff hairs, the axis of the panicle is somewhat extended, so that the numerous branches do not arise from the same point, the glumes are very short. The fact that *Cynodon plectostachyum* was originally described as a species of *Leptochloa* (*Leptochloa plectostachya* K. Schum. in Engler's "Die Pflanzenwelt Ost-Afrikas und der Nachbargebiete", Theil C, 1895, p. 112) also suggests that it differs distinctly from *Cynodon dactylon*.

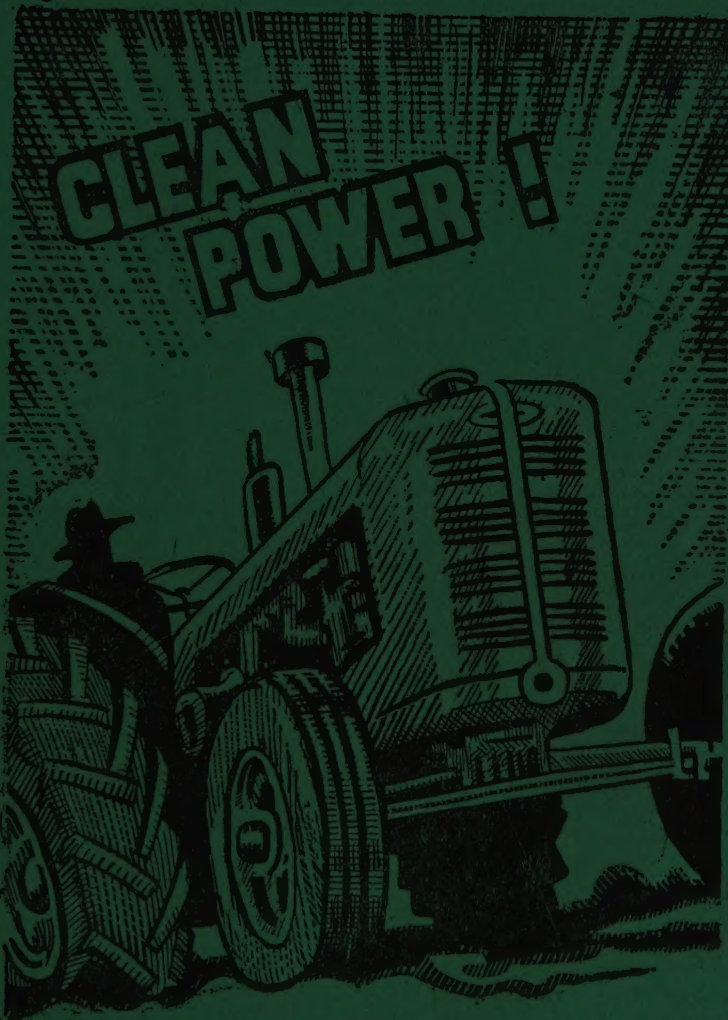
The most conspicuous difference between the two species lies in their flowering heads and spikelets (*see* figs.). *Cynodon dactylon* has flowering heads of the star type, i.e. has a few (usually up to ten) spikes borne on the very end of the stem from one point—exceptionally, vigorous specimens of larger forms may have spikes arranged in two whorls. *Cynodon plectostachyum*, on the other hand, has more numerous (up to 20) spikes which also being borne on top of the stem, are, however, situated, except in poor specimens, in two whorls on a distinct common axis usually ½–1 in. long. Moreover, the young spikes of *Cynodon dactylon* are straight or slightly arching downwards (only ripe spikes of this species can arch upwards), but the spikes of *Cynodon plectostachyum* arch upwards, even when young. The one-floret spikelets densely covering the spikes of both species also have distinct differences which can, however, be better recognized if a lens is used. The spikelets of *Cynodon dactylon* are asymmetrical, slightly shorter (2–2.5 mm. long), with rather long glumes. The upper (longer) glume is usually from one-half to three-quarters (and not less than one-third) the length of the spikelet. The keel of the valve is hairy or hairless, that of the valvule is hairless. *Cynodon plectostachyum* has somewhat longer (2.5–3 mm. long) symmetrical spikelets with very short glumes; the longer glume usually does not exceed one-fourth the length of the spikelet. Both valve and valvule are densely hairy at the keel.

The difference in general appearance, leaves, stems, and stolons is less definable. *Cynodon plectostachyum* is of comparatively vigorous growth, often reaching up to three feet in height when growing in suitable conditions. The stems are fairly stout and the leaves are always hairy. The latter, being long and fairly soft, bend downwards. The stolons are stout, often with arching internodes even when spreading on bare ground. The ends and the young branches of stolons are usually suberect or upright. *Cynodon dactylon* is very variable in its vegetative parts. The stems are six inches to three feet high and the leaves are straight or only slightly arching and usually hairless, though some forms have hairy leaves. On bare ground the stolons spread flat, with horizontal internodes and usually with horizontal ends and young branches, though in dense herbage the stolons are less distinguishable from those of *Cynodon plectostachyum*.

While *Cynodon plectostachyum* is more or less uniform, *Cynodon dactylon* is very variable and is met with in many natural strains of which two strains or ecotypes are the most common. One of them, a riparian ecotype, is of low growth, usually six to twelve inches high, with fine leaves and stems, bright green and somewhat yellowish in colour. This ecotype occurs at river-banks and on riparian flats where it frequently forms a low, dense cover. Although it does not form a large bulk of herbage it is very valuable for grazing and is relished by cattle. The other widely distributed ecotype occurs on dry ground. It is taller, comparatively robust and somewhat similar to *Cynodon plectostachyum* in general appearance, with which species it is often confused. The leaves of this ecotype are usually dull green in colour with a bluish tint.

These two species of *Cynodon* also differ in their distribution in Kenya. *Cynodon dactylon*, an almost cosmopolitan species, occurs throughout the country, while *Cynodon plectostachyum* is distributed in the Rift Valley and eastwards of it, mostly in rather dry areas. This species, which is apparently confined to East Africa, also occurs in Tanganyika from where it was originally described. In the areas where both species occur they often grow in the same communities, but they usually form separate colonies. I have not actually seen any mixed colonies of the two species.

The common and well known name of *Cynodon* is STAR GRASS. While the name COMMON STAR GRASS can be applied to the widely distributed *Cynodon dactylon*, *Cynodon plectostachyum* may be called NAIVASHA STAR GRASS, a name derived from Lake Naivasha in the Rift Valley. This name is also well known in Kenya though it is sometimes applied to *Cynodon dactylon*, probably due to the frequent confusion of the two species.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